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GENERAL ELECTRIC Review

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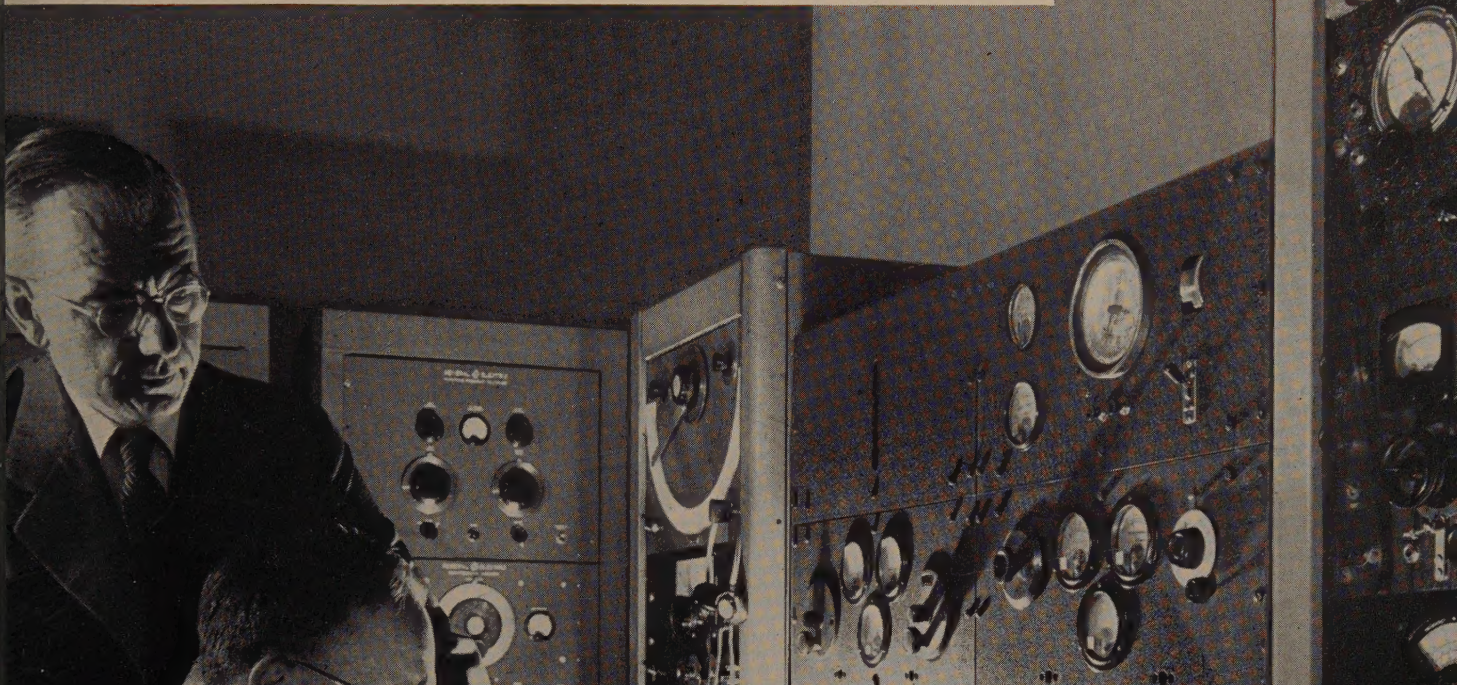


February, 1949

New... ELECTRIC CONNECTORS

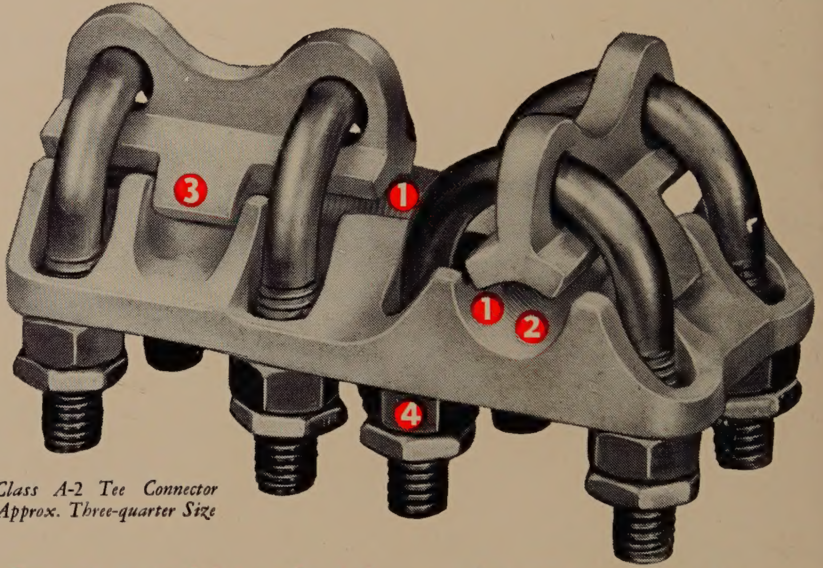
A complete new line of connectors that will simplify your stock problems, reduce system maintenance costs and give you reliable service

① **Serrated contact surfaces** are used on all Class A-1 and A-2 connectors to give extremely high pull-out strength. The connectors are designed to give a permanent, high-conductivity joint that will resist vibration and give positive pressure on the cable at all times.

② **Silver contact surfaces** are a standard feature on *all* General Electric connectors for use with copper conductors. This eliminates oxidation problems, assures lower contact losses, low maintenance, and long life.

③ **Interlocking sides** on all Class A-2 and A-1 connectors confine the strands of the cable within the conductor enclosure, thus obtaining full advantage of the cable's current-carrying capacity.

④ **Non-corrodible hardware** is of high-strength bronze alloy that gives tight and trouble-free service. These connectors can be installed without removing nuts from the clamps; thus eliminating the trouble of lost nuts and washers. The connectors will not twist, distort, or season crack.



Class A-2 Tee Connector
Approx. Three-quarter Size

Correct material for the job means that the composition of the metal alloy used is scientifically varied depending upon the application of the connector. For instance, the copper content is accurately regulated so that the connector carries current equal to the maximum current-carrying capacity of the conductor. The temperature rise of G-E connectors is never greater than the temperature rise in the conductor. These features mean you'll get full power flow through your connectors.

Wide range of sizes means your stock problems will be cut to a minimum when you use these new G-E connectors. With A-1, A-2 and D connectors you can accommodate the same range of conductors—with fewer connector fittings. A complete line of connectors, such as straight, tee, block, angle, parallel, expansion, ground, and many others, is available. Why not place a trial order today with your G-E sales representative and see for yourself how these new connectors can cut down on your stock and maintenance problems? Write for bulletin GEC-400 that contains 44 pages of valuable information on these new connectors.

Apparatus Dept., Section 856, General Electric Company, Schenectady 5, N. Y.

GENERAL ELECTRIC

856-50

GERMANIUM . . .
IMPORTANT NEW SEMICONDUCTOR

In the realm between materials that are good conductors and those that are good insulators lie some materials that now are found to hold promise of unexpected usefulness. Prominent among these so-called semiconductors is germanium, and current studies being made of it are adding to both scientific knowledge and practical applications

By DR. W. CRAWFORD DUNLAP, JR.
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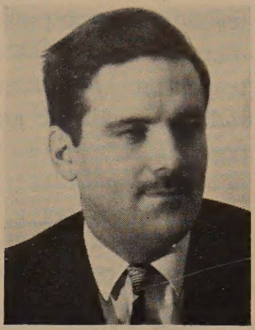

W. C. Dunlap, Jr

GERMANIUM is an element whose properties have been very little studied until recent years, and yet it is one of the most remarkable of the elements. For the purpose of this article, germanium may be classed among the "monatomic semiconductors," a group of elements including boron, silicon, germanium, selenium, and tellurium, and perhaps others. All these elements have properties intermediate between those of insulators and metals, properties which are yet characteristically different from those either of metals or insulators.

PROPERTIES OF SEMICONDUCTORS

Besides possessing electrical conductivity intermediate between that of metals and that of insulators, semiconductors are characterized by an electronic conductivity that increases with temperature over at least *some* temperature range. The latter qualification is important, since pure germanium has a positive (metallic) temperature dependence of resistivity at temperatures between that of liquid nitrogen (−196 C) and room temperature, but the opposite (semiconductor) type of temperature dependence above room temperature. For classification purposes we do not consider ionic conductors as semiconductors.

Semiconductors are of enormous importance at the present time in two complementary fields: (a) the acquisition of new knowledge and new points of view about the structure of matter in the solid state, and (b) the development of new applications of known scientific facts and principles to practical ends.

Electrical conduction in semiconductors is of great interest from the research point of view since it helps us to understand the "excited states" of solids just as optical emission spectra have given us information on the excited states of isolated atoms. Also, just as the study of optical spectra starting before the beginning of the present century led gradually to the Bohr theory of the atom and to our present quantum mechanics, so a study of the electrical conduction and other properties of semiconductors is a main line of attack that may lead us in the near future to new concepts of the solid state.

Likewise, from the more practical point of view, semiconductors are important because of the variability, the diversity, and indeed the peculiarity of many of their properties. The fluorescent lamp, the solid rectifier, the modern photoemissive and photoconductive cells, thermally sensitive resistors, the oxide cathode so important in electron tubes, and a host of other modern devices depend upon properties of one or more semiconductors. Many of these properties are absolutely unique with semiconductors, whereas others are manifested in semiconductors to a much greater degree than in other types of materials.

It is the purpose of this article to point out how recent research on germanium has added to our theoretical knowledge of the solid state and how some of the remarkable properties of this element are being applied to practical devices.

Although space limitations prevent us from going far into the modern theories of the solid state and of conduction phenomena, we will point out an interesting analogy that may help to clarify the present point of view toward semiconductors. In terms of the idea that semiconductors are solids with electrons in excited states, the simplest analogy is to compare a semiconductor with a gas, such as oxygen, containing a few electrons that have been excited to higher quantum energy levels inside the atom by an external agency, such as x-rays. The excited electrons in the gas are still bound to their parent atoms.

If now we were to compress the oxygen into a crystalline lattice, we would find that, because of the greatly increased interaction of neighboring atoms on each other, these electrons would tend to acquire mobility and thus become able to move around through the lattice. A similar effect is involved in the transformation of insulating sodium vapor into conducting sodium metal, where almost all the outer shell electrons are free to move about.

In FIG. 1 is a diagram that illustrates in a simple fashion the conclusions of the modern theory of conduction in solids. At the left-hand side is shown a typical energy-level diagram for a given outer-shell electron in an atom of, say, oxygen. These energy levels are the only energies permitted the electron, according to the quantum theory. Transitions between these energy

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

levels are accompanied by *emission* or *absorption* of a quantum of radiant energy; the energy changed in the transition $\Delta E = h\nu$, where ν is the frequency of the radiation emitted, and Planck's constant is 6.62×10^{-27} erg sec.

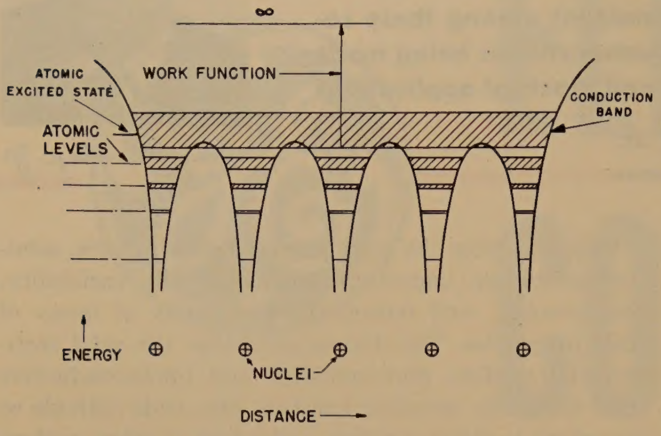

Fig. 1. Diagram showing schematically how free electrons in a semiconductor can be considered in excited states somewhat like those in an excited gas atom. Closer proximity of atoms in the solid than in the gas makes it possible for the electrons in the semiconductor to move about freely through the lattice, whereas the electrons in the gas are bound to their parent atoms unless considerably higher energies are added than is necessary for the solid

Now from the point of view of the theory of conduction in solids, the chief effect of forming a crystal from isolated gas atoms is to *broaden* the atomic energy levels of the outer-shell electrons, and at the same time to narrow the gap between bands. The broadening effect of the coupling between atoms in a crystal is closely analogous to the broadening effect on the frequency response of a tuned L–C circuit when coupled with another similar circuit.

The bands corresponding to filled atomic shells do not generally lead to conduction. However, the band that corresponds to an empty (excited) atomic level normally is not filled in the solid, and thus there is a possibility for conduction. If there are many electrons in the conduction band at absolute zero, the substance is a metal. If there are no electrons in the conduction band at any temperature, the substance is an insulator. If there are electrons in the conduction band at temperatures above 0 K, but none *at* 0 K, the substance is a semiconductor.

Fig. 1 also indicates the work function for a semiconductor whose electrons are concentrated at the bottom of the conduction band. This work function is the work required to lift one of these electrons out of the conduction band to a point outside the surface of the material.

In semiconductors, the free electrons are not usually electrons from the parent lattice, nor are they usually excited by x-rays. Instead, foreign or *impurity* atoms act as the source of electrons in many cases, and the excitation to the excited states is the result of thermal excitation arising from the vibrations of the lattice. Thus we arrive at the usual picture that a semiconductor is an insulator in which impurities furnish a measurable conductivity. At room temperature, the concentration of free electrons in germanium may be as small as that corresponding to one electron per 10^8 to 10^9 atoms. Very impure germanium, on the other hand, may be almost as conducting as some metals (resistivity 0.001 ohm cm*); that is, there is approximately one electron to 10^3 atoms. This variability of resistivity with impurity concentration gives us an invaluable tool in providing semiconductors for specific applications.

The fact that thermal excitation is required in order to produce free electrons in a semiconductor means that the resistivity must decrease with increasing temperature over some temperature range. That is, on lowering the temperature some of the free electrons are "frozen out" and the resistivity is raised (provided the decrease in free electron density is not overbalanced by the well-known increase in mean free path with decreasing temperature).

Another important property of some semiconductors is that electrons can also be liberated by optical radiation. This leads to *photoconductivity*. When the optical electrons return to their normal states, they may radiate light just as do electrons in isolated atoms. This phenomenon is called *fluorescence*, or *phosphorescence* in the case that the emission follows the absorption by an appreciable time lag.

Other properties of semiconductors that are of great fundamental and practical importance include the contact properties of semiconductors with metals. These properties have led to solid-contact rectifiers, photovoltaic cells, and the "transistor." The photovoltaic cell is essentially a rectifier that creates its own voltage when the semiconductor-metal boundary is illuminated with visible radiation.

GENERAL AND CHEMICAL PROPERTIES OF GERMANIUM

Germanium is closely related to carbon, silicon, and tin with respect to many physical and chemical properties. A comparison of some of these properties is given in Table I. Although the properties given are for the diamond-cubic forms only, it should be remembered that carbon also occurs in the hexagonal crystal form (graphite), as does silicon, whereas tin has allotropic crystal forms in the diamond-cubic, the rhombic, and the tetrahedral patterns. Germanium appears to crystallize only according to the diamond-cubic pattern. A model of this type of structure is shown in Fig. 2. Although the atoms themselves do not form a simple cube, it is easy to see how the cube can be envisioned as the basis for the diamond-cubic lattice.

Germanium is chemically a close relative of carbon and silicon, and like these elements it is capable of forming long-chain hydrides and other compounds analogous to those of organic chemistry.(1)

The discovery of germanium was made in 1886 by the German chemist Winkler. The method usually used in the preparation of the element is the reduction

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*The ohm cm, the unit of resistivity in practical electrical units, is the resistance between opposite faces of a cube of material one centimeter on a side.

(1) Numbered references are listed at the end of the article.

TABLE I

COMPARISON OF SOME PROPERTIES OF CARBON, SILICON, GERMANIUM, AND TIN

Property	Carbon	Silicon	Germanium	Tin
Lattice Form	Diamond Cubic Hexagonal (graphite)	Diamond Hexagonal	Diamond	Diamond (gray) Tetragonal Rhombic
Melting point (deg. C)	3500	1420	958	231.9
Boiling point (deg. C)	4200(?)	2600	≈2700	2270
Density (gm/cm^3)	3.51	2.4	5.35	5.75
Appearance	Transparent crystal	Dark metallic	Bright metallic	Bright metallic
Electrical resistivity (25 C)	$>10^6$ ohm cm but highly variable	0.001 to 1 ohm cm	0.001 to 50 ohm cm	Metallic
Classification	Insulator	Semiconductor	Semiconductor	Metal

Data are for diamond-cubic forms where properties vary with crystal pattern, except for tin whose diamond form is stable only below 18 C.

f the oxide in hydrogen at a temperature of about 600 C. The oxide is usually refined from residues of zinc nining. Germanium has also been prepared in small mounts by decomposition of some of its volatile comounds, such as germanium tetrachloride.

Germanium powder formed by reduction of the oxide s melted to form an ingot. The properties of the product re dependent to a great extent on the care with which he melting and the reduction are done, and upon the tmosphere of melting, and the heat treatment of the ngot. Dry nitrogen, dry hydrogen, dry helium, and acuum melting are the most common methods of meltng germanium powder. In all these methods, traces of vater vapor appear to have the effect of increasing the esistivity of the product.

The room-temperature resistivity of germanium roduced by those methods may be as high as 50 ohm cm or as low as 0.001 ohm cm, depending on the impurity concentration and the type of impurity.

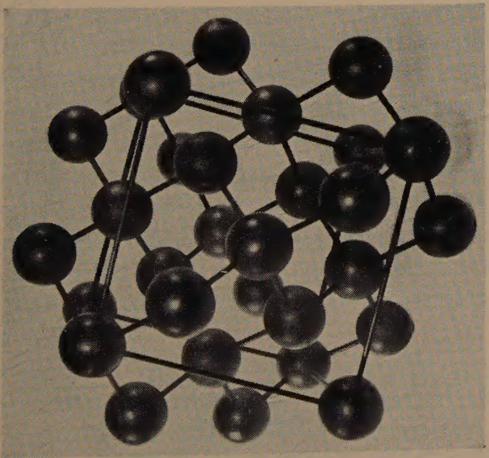


Fig. 2. A schematic model of the diamond-cubic lattice, the basic structure for crystals of diamond, silicon, germanium, and gray tin

Sensitivity of germanium to impurity concentration may be judged by the fact that Hall-effect studies show that there may be as few as one impurity electron for every 10^8 to 10^9 atoms of germanium. Assuming that some impurities are capable of yielding one electron for every atom, it will be noted that concentrations of some impurities of less than one part per million may be very important in determining the conduction properties. Aluminum, tin, arsenic, and gallium are considered effective in "doping" germanium to lower its resistivity.

Generally containers used for heating and handling germanium are made of quartz or graphite. There appears to be little or no contamination of germanium by these materials, compared to the variability of the product known to arise from other sources.

PHYSICAL PROPERTIES

One of the many interesting properties of germanium and some other semiconductors is their strong metallic-type optical reflection. To show this effect, an ingot of germanium is pictured in FIG. 3. Germanium, it is seen, possesses a brilliant silvery reflection from smooth and polished surfaces. The actual reflectance is of the order of 50 percent. "Fool's gold," or iron pyrites, is another well-known semiconductor that exhibits strong reflection, in this case yellow.

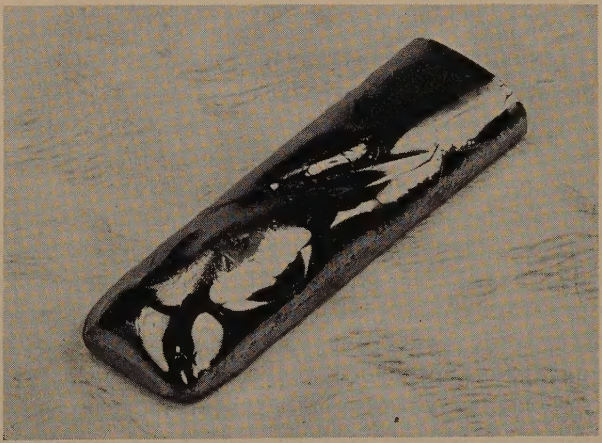


Fig. 3. An ingot of germanium photographed to show the strong metallic-type reflection characteristic of this material and of a few of the other semiconductors

The metallic reflection of these semiconductors is an anomalous property. In metals, the metallic-type reflection can be ascribed directly to the action of the enormous number of free electrons. The reflected light is, according to the electromagnetic theory, simply the light radiated by the electrons near the surface of the metal, vibrating in response to the action of the incident light. Germanium, with less than one millionth of the free electron density of aluminum or silver, nevertheless has a metallic reflectance almost equalling that of these metals. Apparently the atomic electrons of germanium are able to vibrate to a certain extent under the influence of a beam of light, even though most of these electrons are not free to carry current through the material.

Mechanically, germanium is hard and brittle. It is difficult to machine and consequently is usually cast into desired forms, or sawed with a diamond wheel.

TABLE II

SUMMARY OF PROPERTIES OF GERMANIUM

Atomic weight	72.60
Atomic number	32
Atomic radius$^{(a)}$	1.22 Å
Compressibility $^{(b)}$	1.4×10^{12} dyne/cm^2
Electrical resistivity	0.001 to 50 ohm cm
Hall coefficient$^{(c)}$	100×10^{-9} to $800{,}000 \times 10^{-9}$ volt cm/amp gauss
Optical reflectivity	≈ 50 percent
Electron mobility 25 C$^{(c)}$	< 3000 cm^2/volt sec (maximum)
Magnetic susceptibility$^{(b)}$	0.12×10^{-6} cgsm
Specific heat$^{(b)}$	0.072 cal/gm C
Debye temperature$^{(d)}$	290 K

(a) *Handbook of Chemistry and Physics*, 30th Ed.
(b) Int. Critical Tables, 1933.
(c) Unpublished results of the author, from the ratio of the Hall coefficient to the resistivity.
(d) Appendix II, Mott and Jones, *Theory of Metals and Alloys* (Oxford, 1939).

Some of germanium's properties other than those listed in Table I are given in Table II; but many of the mechanical and physical properties have been studied very little as yet.

ELECTRICAL PROPERTIES

Germanium is of especial interest today because of its numerous remarkable electrical properties. Already mentioned, for example, is the wide range of resistivity, roughly a factor of 25,000, that can be attained by use of the proper concentration of impurities.

Besides the property that impurities contribute to its resistivity, germanium, unlike many other semiconductors, has the property of an appreciable room-temperature conductivity even when highly purified. This intrinsic conductivity can be determined from the temperature dependence of the total resistivity, and corresponds to a resistivity of about 100 ohm cm. It appears that further purification of germanium cannot raise the resistivity beyond this value.

Like the impurity resistivity, the intrinsic resistivity is dependent on temperature, but in a different way. Below room temperature, it is usually only a small fraction of the total. Above room temperature, for high-resistivity germanium with $\rho \approx 10$ ohm cm or higher, the intrinsic conductivity becomes predominant and the resistivity drops with increasing temperature. The combination of these two contributions to the resistivity leads to a resistivity curve such as that shown in FIG. 4. Hall-effect studies show that the low-temperature variation of ρ is due to change of the mean free path with temperature, whereas the resistivity in the "intrinsic" region changes mainly because atomic electrons are being excited into the conducting state by thermal vibrations. Different samples of germanium may reach the intrinsic region at different temperatures because of their varying impurity conductivity. Once in the intrinsic region they all have roughly the same conductivity.

At temperatures lower than those shown in FIG. 4, it is to be expected that the resistivity rises again. This effect is the result of inactivation of the impurity electrons because the thermal vibrations of the lattice are no longer sufficiently energetic to supply the very small energy (≈ 0.01 electron volt) required to free the electrons from their impurity centers.

Besides exhibiting those peculiarities of resistivity, germanium is also remarkable for its Hall effect and thermoelectric properties. The Hall effect involves the production of a voltage across the sides of a conducting strip when a magnetic field is applied normal both to the current in the conductor and to the face of the conductor, as indicated in FIG. 5. The Hall voltage is determined by the equation $V = R\ H\ I/t$, where R is the Hall coefficient of the material, H the magnetic field strength, I the current, and t the thickness of the sample in the direction of the magnetic field. The Hall effect is important in research since it helps to determine the number of conduction carriers, and, in combination with the resistivity, also the mean free path and mobility. The temperature dependence of the Hall coefficient is shown in FIG. 4. When the Hall coefficient is constant, the number of free electrons is constant, as in the impurity region. In the intrinsic region, the Hall coefficient parallels the resistivity.

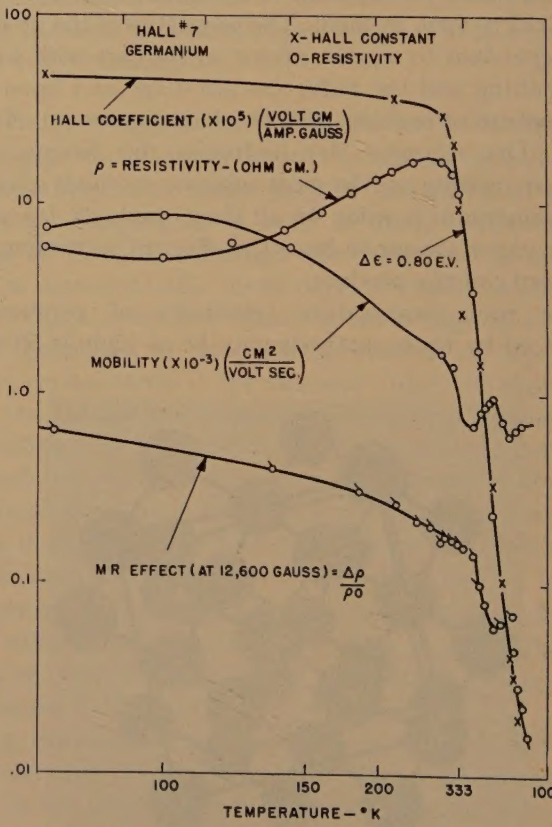


Fig. 4. Plot showing the dependence of the resistivity, the Hall effect, the mobility, and the magneto-resistance (change of resistance in a magnetic field) on temperature for a typical sample of germanium

Another remarkable property of germanium is found rom Hall-effect measurements, namely, the high value f mobility (R/ρ). It appears that electrons in germaium have a higher value of mobility—that is, they can nove around more easily under the influence of an lectric field—than in any other solid conductor with he possible exception of bismuth. The value of the nobility has been found to be as high as 3000 cm²/volt ec at room temperature, whereas in ordinary semionductors and metals the corresponding value is usully in the 20-100 range at room temperature.

The Hall effect is also of interest for translating the ffect of a static magnetic field into current. Pearson,(2) or example, has described a gaussmeter based on the ensitivity of a germanium crystal to a magnetic field.

Another interesting property of germanium is the lependence of the resistivity on the magnetic field trength.(3) The effect increases with increasing reistivity of the sample. High-resistivity samples someimes show a 25-percent increase of resistivity when laced in a magnetic field of 15,000 gauss at room emperature. At liquid-nitrogen temperature (−196 C), he effect is even larger, and some samples show a loubling of the resistivity in the same field. The temerature dependence of this "magnetoresistance" is lso indicated in Fig. 4.

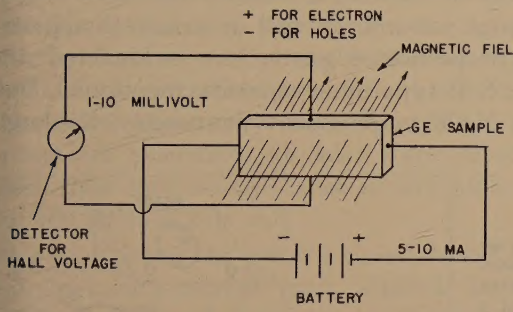


Fig. 5. Diagram illustrating the method of measuring the Hall effect. Potentiometers are used for all potential measurements to avoid errors arising from contact resistances and other sources of error

The presence of a large magnetoresistance in a sample f germanium is usually accompanied by a decreasing Hall coefficient in an increasing magnetic field. Just ow close the connection is between the two effects is ot yet clear. Both effects appear to be related, to some xtent at least, to inhomogeneity in the sample.

The thermoelectric power is a property that is, like he Hall effect, much larger in germanium and other emiconductors than in metals. It will be remembered hat the thermoelectric power is determined by attachng two pieces of a good metallic conductor to the naterial under study and heating one of the junctions, eaving the other cool. A voltage, called the thermolectric voltage, is found to appear across the ends of he conductor.

Whereas such common thermocouples as copper-onstantan yield thermoelectric voltages of the order f 40 microvolts per degree C, high-resistivity germaium when made into a thermocouple as just described ields voltages of the order of millivolts per degree C.

Like the Hall effect, also, the thermoelectric power is useful for analyzing semiconductors for the number and the type of the conducting carriers. Unfortunately, results obtained from thermoelectric measurements are not as easy to interpret as those obtained from study of the Hall effect.

The possibilities for the use of germanium thermocouples in the field of measurement and control are considerable. There appears, however, to be a low efficiency for the conversion of heat into electrical energy by use of germanium, which may limit this type of application. Several other semiconductors, including lead sulfide, appear somewhat more promising in this respect.(4)

One reason for the low-power-conversion efficiency of germanium thermocouples is that much energy is lost between the hot and the cold ends of the germanium because of the extraordinarily high thermal conductivity of germanium. Like the metallic reflection, this thermal conductivity is an anomalous property. The high thermal conductivity of metals is the result of a very high density of free electrons, which are the actual conductors of the heat. Again as in the case of optical reflection, germanium, with less than one millionth the electron supply of copper or silver, has a thermal conductivity one fourth to one third that of these good heat-conducting metals. The discrepancy for the case of germanium can probably be ascribed to a very large contribution to thermal conductivity by the material's crystal lattice itself.

As mentioned previously, both the Hall effect and the thermoelectric effect can be used for estimating the nature and the number of the charge carriers in a conductor. Generally it is observed, both with metals and semiconductors, that the sign of the Hall voltage is just what would be expected if normal negative electrons carried the conduction current and were deflected in the magnetic field. Many metals and semiconductors, however, including some samples of germanium, show a reversed Hall effect, as if a positive particle were doing the conducting instead of the usual negative electron. It has been found that although such positive particles do not actually exist in the crystal, under some conditions the electrons in the crystal react in such a way that positive particles appear to be conducting. The positive particles are called "positive holes." Germanium, depending on the type of impurity, may be either an electronic (N-type), or a positive-hole (P-type) semiconductor.

It would be out of place here to attempt to give a theory of positive holes, since the effects involved are essentially of quantum mechanical nature.(5) We may say, however, that the positive hole arises from an electron vacancy in the electron system about the atoms. This vacancy is usually caused by the absorption of one of the atomic electrons by an impurity, such as oxygen, an action that tends to form negative ions. The remaining electrons react to external forces, such as those exerted in electric and magnetic fields, in such a way that the effect is that of a positive electron located at the vacancy. A convenient picture for illustrating the formation of electrons and holes in semiconductors is shown in Fig. 6.

In Fig. 6 are illustrated the various ways in which free electrons or free holes can be produced in a semiconductor. The energy-band picture is essentially the same as that in Fig. 1, with the atomic nuclei removed. For *intrinsic* conduction, both free electrons and free holes are created by excitation of an atomic electron to the filled band. For impurities that *furnish* electrons, the hole is *bound* (positive ion) and only the electron becomes free. Conversely, when the impurities *accept* electrons, the electrons are bound in impurities and only the holes are free to conduct electricity.

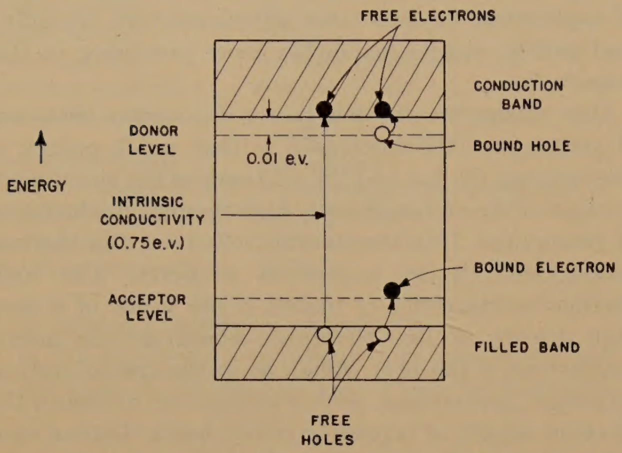


Fig. 6. A band representation of semiconductors indicating how free electrons and positive holes can be created. "Donor" impurity atoms may furnish an electron in the excited state, or conduction band. On the other hand, an "acceptor" impurity may remove an electron from an atomic shell of electrons and thus leave a mobile "positive hole." In intrinsic conduction, direct excitation of an atomic electron creates a free electron and a free positive hole

The properties of P-type germanium are much like those of the N-type, except for such effects as reversal of the sign of the Hall effect, the thermoelectric effect, and the direction of rectification. A more significant difference seems to be that P-type germanium does not make good point-contact rectifiers. Just why this is so is not yet well understood.

It should be mentioned that P-type conduction is important with respect to intrinsic conductivity, since excitation of an electron to the conducting state leaves behind just the type of electron vacancy that has been described as the positive hole. Since the positive hole has mobility, the current is the result of a mixture of electrons and holes. Recent work indicates that because of their higher energy, the electrons are somewhat more mobile than the holes, by a factor of about two.(6)

All those three effects, namely the thermoelectric effect, the Hall effect, and the direction of rectification, can be used to determine the type of conduction in a given sample of germanium, or at least the predominant type, since if conduction is mixed only the net effect is observed. A simple circuit for a testing method utilizing the thermoelectric effect is shown in Fig. 7.(7) A platinum needle embedded in the tip of a small soldering iron is the basic tool. The contact of the point of the needle with the germanium provides the hot junction. The contact of the germanium sample with the base plate provides the cold junction. The direction of deflection of the galvanometer indicates the type of conduction. For N-type germanium in contact with any good metal, the hot junction becomes positively charged, and for P-type germanium it becomes negatively charged. By means of this test it is possible to show that parts of some samples are N-type, other parts P-type. In addition, of course, each part may contain some contribution of the other type of conduction, since only the predominant type of conduction is determined.

There appear to be interesting contact properties between the N- and the P-type regions. Benzer(8), for example, has shown that such a boundary is photosensitive. He has also shown that high-frequency oscillations of a type not yet completely understood can be set up in a circuit containing such a boundary.

Experimental research as well as practical application of the properties of germanium is hindered not only by the N-P type inhomogeneity mentioned, but also because of the more usual type, namely, the large variation of resistivity often found throughout rather small samples. Thus it is possible to find a 50-fold, or greater, variation in resistivity across an ingot of germanium. Generally, the lower resistivity is at the top of the ingot and the higher at the bottom. With the production methods now being used, the resistivity across an ingot will usually vary by a factor of only a few times at the most.

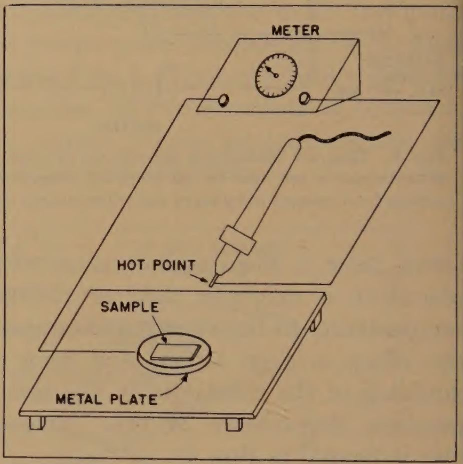


Fig. 7. A simple arrangement for determining the sign of the charge carriers in a semiconductor. By moving the hot probe over the surface of the sample under test, and observing the direction of deflection of the galvanometer, one can explore the surface of the semiconductor for N- and P-type regions

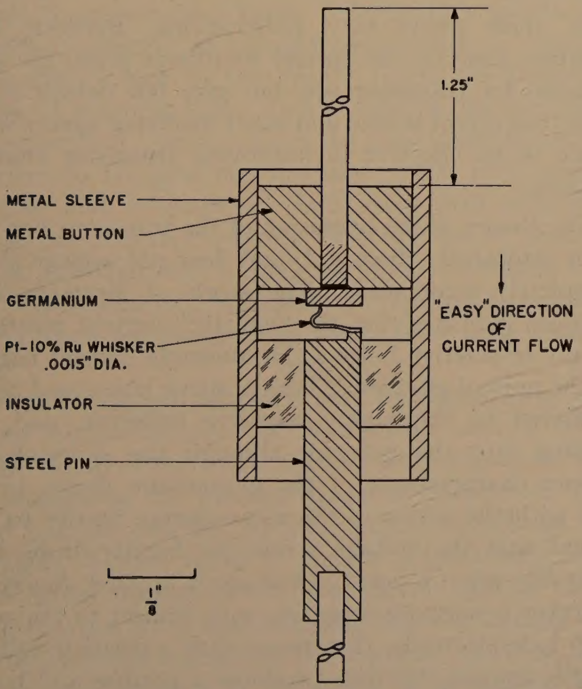
RECTIFICATION PROPERTIES

The electrical properties of germanium have been very little studied until recent years. During World War II attention was focussed upon germanium as a possible material for high-frequency detector crystals. Much work was done, in both the research and development fields, at Purdue University, the Bell Telephone Laboratories, the General Electric Research Laboratory, the M.I.T. Radiation Laboratory, and at other institutions. Much of this work has been summarized in a book by Torrey and Whitmer.(6) This book also gives some consideration to the basic properties of germanium, silicon, and other semiconductors.

Most of the wartime attention to germanium was directed to the problem of detecting microwaves with germanium point-plane detectors. For this work low-resistivity germanium ($\rho \approx 0.01$ ohm cm) obtained by "doping" with antimony or a similar donor material was used. The rectifiers obtained were characterized by very low resistance in the forward direction, and by low breakdown voltages in the reverse direction (of the order of a few volts). Welded-contact rectifiers for this purpose were developed in the General Electric Research Laboratory by H. Q. North.(9) This type of unit has great mechanical strength and desirable rectification characteristics, compared to the standard pressure-contact point-plane rectifier.

It has been found that construction of the same type of rectifier that was used for microwave detectors, but made with high-resistivity germanium instead of low-resistivity material, yields units having a very much higher inverse voltage at breakdown than the older unit. Units withstanding several hundred volts in the backward direction were prepared. Of course these units are unsuitable for microwave detectors because also their forward resistance is very high, of the order of 100 ohms at one volt.

FIG. 8 shows the constructional details of one design of high-back-voltage unit studied in the General Electric Research Laboratory. This type of unit was developed by E. F. Hennelly. These units generally have a forward resistance of 100–200 ohms, a back resistance of several hundred thousand, and a peak inverse voltage in the range of 60–100 volts. Units of this type are not permanently damaged by breakdown, within the limits of melting the whisker by dissipation of excessive amounts of power. The units carry currents of the order 100 ma (rms) in rectifier circuits. A typical characteristic is shown in FIG. 9. A feature of some interest is the "negative resistance" region at *A*.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METAL BUTTON
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Pt-10% Ru WHISKER .0015" DIA.
INSULATOR
STEEL PIN
1/8"

Fig. 8. Diagram of the construction of a typical high-inverse-voltage diode. In this type of unit the "whisker" may be welded to the germanium by passage of several hundred milliamperes current in the forward direction—that is, in the direction of easy flow

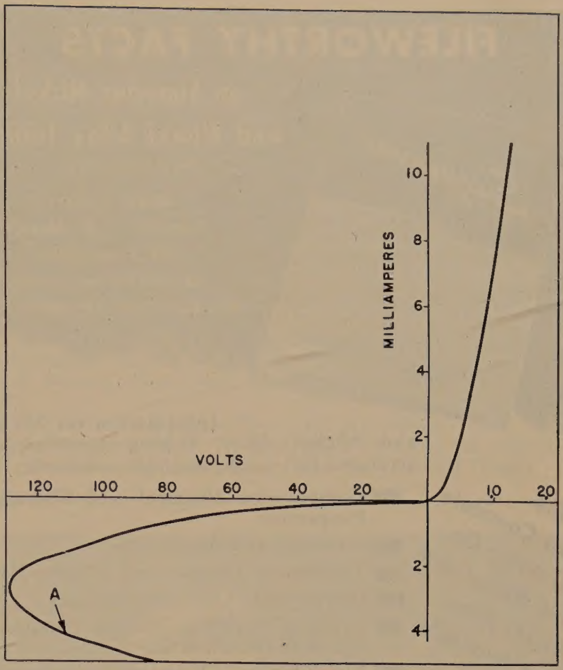


Fig. 9. Plot of the rectification characteristic of a typical high-inverse-voltage diode. The forward resistance is essentially that due only to the germanium at the point of contact. The back resistance is the result of a potential barrier arising from the work function difference of the metal and the semiconductor. Region *A* is a region of negative resistance, which makes possible the use of the diode as an oscillator

Germanium for high-voltage units is usually etched or polished before the point is applied, and welding may or may not be used.

THE TRANSISTOR

The foregoing brief consideration given to the high-back-voltage germanium diode will aid in understanding the performance of the remarkable new germanium triode recently announced by the Bell Telephone Laboratories(10) and illustrated in FIG. 10. This triode is very similar basically to the diode, except that a second whisker located very close (0.002 in.) to the first is used as a control electrode, much as the grid of a vacuum tube is used.

The revolutionary feature of the transistor stems from its ability to amplify an input signal to 50 times in voltage and 100 times in power. These figures are of course those characteristic of the preliminary designs of the transistor and cannot be considered to be the ultimate.

To give a preliminary comparison between the transistor and the vacuum triode, it appears even at this early stage of transistor development that the small size, the simple and rugged construction, the absence of high vacua, the absence of heater currents, and the presumed long life of the transistor compared

(Continued on next page)

to that of the vacuum tube probably will lead to a preference for the former in some applications heretofore using the tube exclusively.

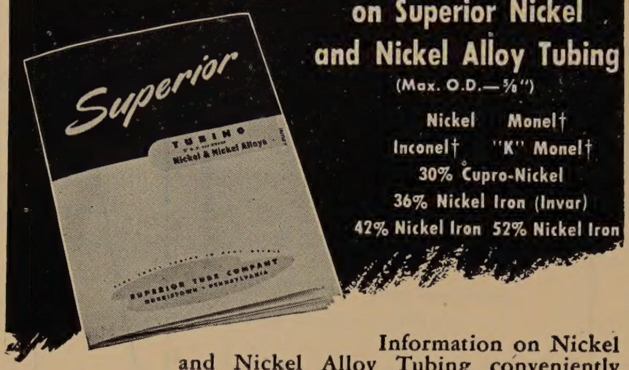
The principal apparent weaknesses of the transistor lie in its small power output, a maximum of about 25 milliwatts per unit, and the low input impedance which tends to limit the flexibility of the unit. The transistor also is said to have a somewhat higher noise level than a comparable vacuum tube. Just how far these shortcomings of the transistor can be overcome cannot be judged at present.

The action of the transistor depends upon the mutual interactions of two germanium diodes located on the same block of germanium, as shown in FIG. 10. Although the two diodes have essentially the same characteristics, one electrode (the control or "emitter") is operated in the forward direction and the other (the plate or "collector" electrode) in the back direction. Thus the input impedance of the transistor is roughly that of the forward impedance of the ordinary high-back-voltage diode, several hundred ohms at most. Conversely, the output impedance is of the same order as the back resistance of the diode, although actually, by means of a special treatment given the germanium, the Bell Telephone Laboratories have produced transistors wherein the impedance is somewhat lower, of the order of 10,000 to 100,000 ohms.

As is clear from FIG. 10, a bias voltage of about one volt is applied to the input circuit, and a voltage of 40–50 volts to the output circuit. In both circuits, currents of the order of a few milliamperes will then pass. A signal applied to the input circuit appears as amplified voltage in the output circuit.

In their preliminary publications, Bardeen and Brattain mention the special treatment given the germanium for transistor use, but give few details other than that glycol borate and other oxidizing agents were found to be effective in improving transistor characteristics.

The theory of the operation of the transistor has not been extensively discussed, and does not appear to be completely understood. The work of Brattain and Bardeen indicates that the "emitter" current creates a supply of positive holes as an alternate current carrier to the normal electron. These positive holes tend to be attracted to the highly negative collector, and, on passing into the collector through the space-charge barrier characteristic of the germanium diode, interfere with the action of the space-charge barrier to the extent that the voltage across the barrier drops considerably when a positive voltage is applied. Since the collector is normally negative with respect to the common base electrode, this means that a positive voltage on the control electrode produces a *positive* and larger voltage change in the output. In this respect, the characteristic of the transistor is opposite to that of the vacuum triode, which inverts the phase of the input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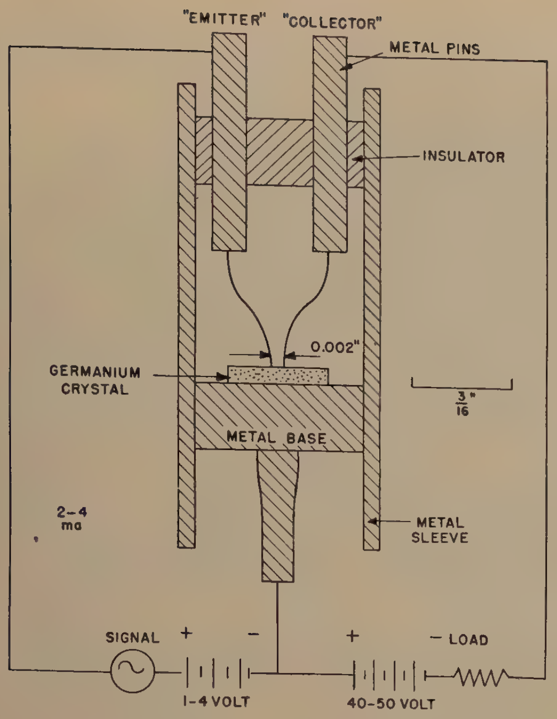

Fig. 10 A schematic diagram of the type of transistor recently announced by the Bell Telephone Laboratories. It consists essentially of two diodes constructed on the same block of germanium. One of the diodes operates in the forward direction and the other in the reverse direction. The two points are located not much more than a few mils apart to obtain amplification, according to Bardeen and Brattain, the research scientists who disclosed the device shown. The "emitter" is biased a few volts positive, the "collector," 40 or 50 volts negative, so that both electrodes carry a few milliamperes current. A signal applied to the emitter is amplified about 50 times in voltage and 100 times in power by this type of unit

signal by giving a *negative* output pulse when the input is positive.

The transistor has been found by the Bell Laboratories group to operate effectively at frequencies up to about 5 megacycles. Those investigators ascribe the failure to operate at higher frequencies to a "transit-time-effect" such as that which limits the frequency range of vacuum tubes. In the case of the transistor, the important transit time is the time taken for charge carriers to traverse the distance (0.002 in.) between emitter and collector at their usual drift velocities. Since the effective velocity of electrons in solids is much less than that in high vacuum, the transit time in the solid case can reasonably be expected to be much larger than for comparable dimensions in a vacuum tube.

No attempt can be made here to evaluate the economic factors involved in the possible uses of transistors. Some of the more obvious advantages and disadvantages of the present design of transistors have been pointed out, but to what extent transistors will supplant vacuum tubes in present applications, or to what extent transistors will be applied to uses for which present types of vacuum amplifiers are not suitable can hardly be predicted as yet. It is evident, however, that recent developments in the study of germanium and other semiconductors will have a profound influence on both the practical application of scientific principles and on the search for new knowledge.

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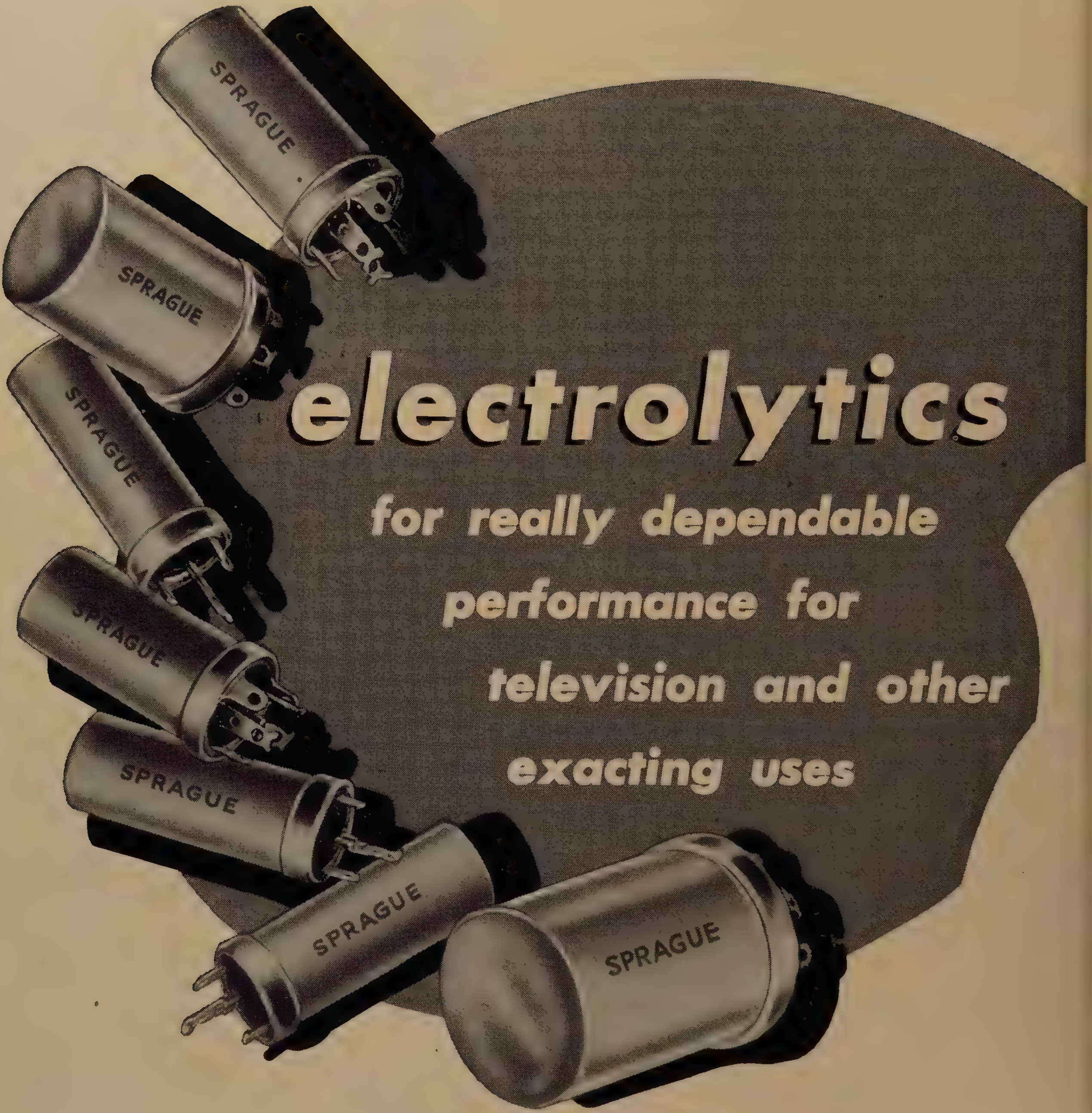
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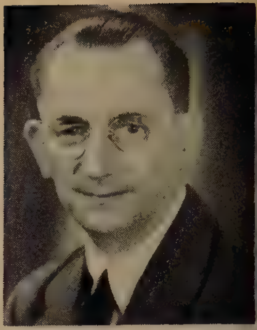
INDIVIDUALISM OR STANDARDIZATION OF SWITCHGEAR EQUIPMENTS

A review of the progress made from individualism to standardization in switchgear rated up to 15 kv and 500,000-kva interrupting capacity. How, by co-operative endeavor, Industry Standard Equipments are being produced with many advantages to their users



Clarence Dey

By CLARENCE DEY
Section Engineer, Switchgear Divisions
Philadelphia Works, General Electric Company

STANDARDIZATION has become something of a watchword in modern industry. Because the term will be used frequently in this article, a brief of the sense in which it will be used is advisable.

Standardization is not stagnation. It provides the opportunity to concentrate design effort on the most important features. It is not "riding off in all directions." It accelerates development and incorporates improvements promptly. It allows maintenance of a continuous check of performance in manufacturing routine. For example, when large quantities of a few ratings of a device are being made, production-line samples can be selected at random and tested to destruction as a check on performance. This would not be economically feasible if small quantities of many ratings were being made. Standardization lowers costs, and at the same time it improves quality through improved accuracy in manufacture. It shortens manufacturing time, thus improving delivery. To repeat, standardization is *progress*, not stagnation.

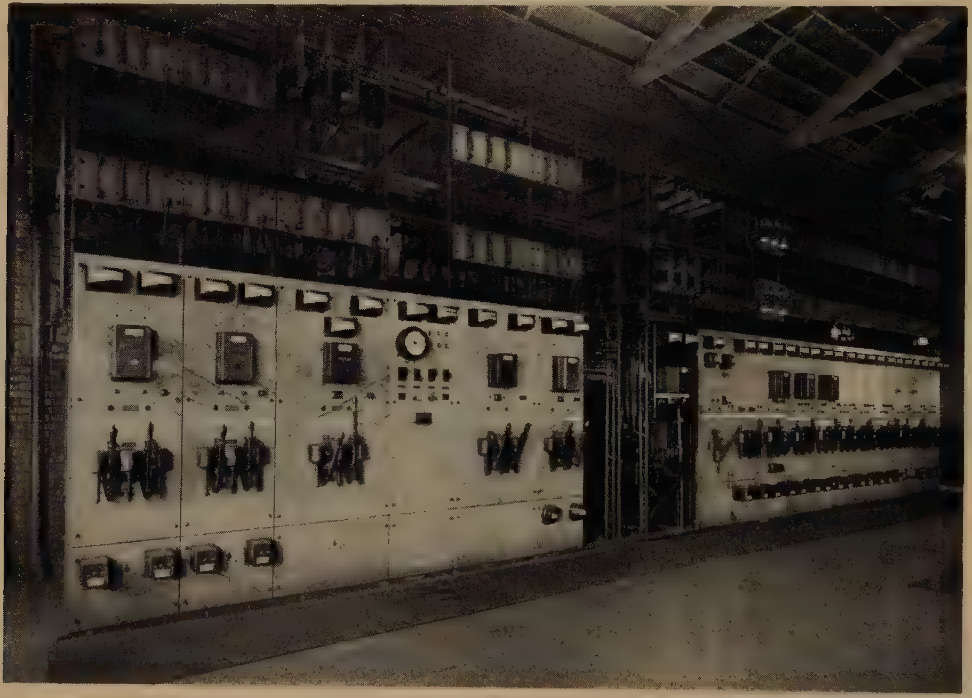


Fig. 1. **BEFORE:** Example of an installation of open-type switchgear. Such design was considered good 30 years ago but is inadequate for today's service. (See also Fig. 2.)

TREND TOWARD STANDARDIZATION

For years, switchboards and switchgear have in general been engineered and designed individually in accordance with many different application requirements, which in turn were dictated by the particular project or established local practices. The introduction of metal-enclosed gear in the "20's" started a trend toward standardization, although it may not have been so recognized then. By the time World War II engulfed the industry, a considerable amount of standardization had been effected in the many devices which make up an equipment.

Metal-clad switchgear with removable breakers was by that time generally accepted as providing the best and most economical equipment for application up to 15 kv and 500,000-kva interrupting rating. For higher voltage ratings and higher interrupting requirements,

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

tation-type metal-enclosed structures were fairly well-stablished in their field of application, but to a great xtent they were still designed from individualized oncepts. Although some standardization has since been ccomplished in the latter type of equipment, the hysical size and arrangements introduce variables hich alter the viewpoint sufficiently to warrant a ifferent approach and treatment of the entire developnent.

Fundamentally, the objectives of standardization re the same for both those types of equipment; but or the purposes of this article, equipment for applicaions up to only 15 kv and 500,000-kva interrupting apacity will be considered, leaving the higher-rated tation equipments to be treated in their own category.

As an example of progress made up to the beginning f World War II, consider the substation equipment hown in Fig. 1. Thirty years ago, it was considered ood equipment, and it was good equipment as measred by practices then in vogue. Today, we know that ; is unsafe to operate, has inadequate insulation for nodern power practices, and is expensive to install and naintain. That same substation is shown in Fig. 2 fter replacement with modern metal-enclosed equipnent. In addition to eliminating the operating hazards f the older design, it provides better control and proection, easier operation, less installation and engineerng expense, and lower maintenance costs. These are vell-established and proved facts.

TANDARDIZATION OF COMPONENTS AND EQUIPMENT

It is not generally recognized, however, that the dvantages just mentioned were made possible by tandardization of the component devices of the equipnent—a development which was carried out by standrdizing committees embracing manufacturers and nany types of users. This standardization program ncluded such items as:

- Instruments and relays in standard-size cases.
- Standard switches having universal application.
- Metal-enclosed gear with standard compartmentation.
- Removable interchangeable breakers.
- Standardization of breaker ratings.
- Standardization of insulation levels.
- Standard methods of short-circuit calculations.

'hose items are indicative of the diversified interests vhich were contributing their efforts to standardization.

While the activity of component standardization was argely suspended during the war, the opposite was rue of equipment standardization. The wartime probem was to achieve volume production *with* insufficient naterial and manpower, and *without* sacrifice of any ualities or workmanship that would jeopardize the erformance of the equipment.

Taking into account such factors as material content, ngineering and manufacturing manpower, general daptability, and safety, a careful consideration of all vailable types of equipment resulted in the adoption of factory-assembled metal-clad gear with removable breakers as the best solution to this wartime problem.

In this manner, the trend which was developing before the war was made an established procedure, and that resulted in partial standardization of switchgear equipments. Actually, the process was carried even further. The urgency of the times demanded that existing, developed designs be used wherever possible in order to reduce engineering time and manpower. Thus it was that equipments produced for one application were transferred to others while still in process of assembly, or even after they had been shipped from the factory. Those expediencies were made possible because basically the standardized equipment was interchangeable in its component parts, and the equipment of any one circuit unit was adaptable to any application where that particular type of circuit appeared.

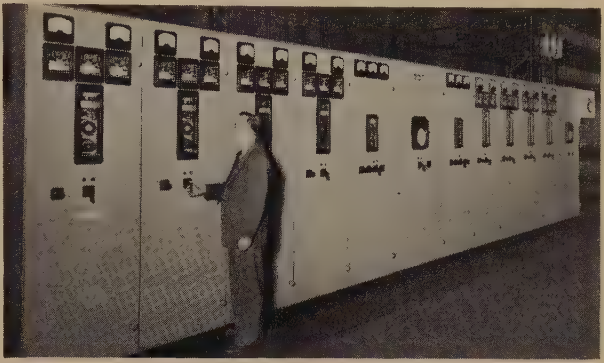


Fig. 2. **AFTER:** The switchgear shown in Fig. 1 was replaced by this modern metal-enclosed equipment

That those methods did accomplish the purpose is a matter of record—a record of which the entire electrical industry has reason to be proud. Standardization of entire equipments by circuits produced more from less, and in a shorter time, and for a higher level of dependability. Perhaps we did not obtain all the luxuries of individual preferences to which we had been accustomed, but reliable equipment was made available when most urgently needed.

What was accomplished in wartime can be extended more efficiently in peacetime when it is possible to give the methods a more careful and comprehensive analysis. If standardization of equipments by circuits in a restricted way will produce desirable benefits, is it not reasonable to expect infinitely greater benefits from a broad collective standardization policy? Is it not possible to create for a given circuit a standard unit that will give a definite combination of metering, control, and protective functions which can be used wherever that particular circuit appears?

STANDARDIZATION BASED ON RESULTS

Although we now have many varieties of "standards" in the electrical industry, concentration on the broader aspect of functional or objective standards should go far to focus our thinking and resolve our differences. For example, a synchronous-motor control and starting equipment, engineered and designed as a "standard" for the John Doe Company of Chicago could not be considered an industry-wide standard unless the same complement of functions connected to operate in the same manner could be used for all duplicating applications. Notice that it is the *results* which are emphasized as being the basis of standardization. It would be expected that the means used to produce these result would vary between manufacturers in our typica American economy of competition.

It is imperative that standards avoid being restric tive, except for the purpose of preventing retrogression Rather they should be objective and broad in applica tion to permit prompt utilization of scientific improve

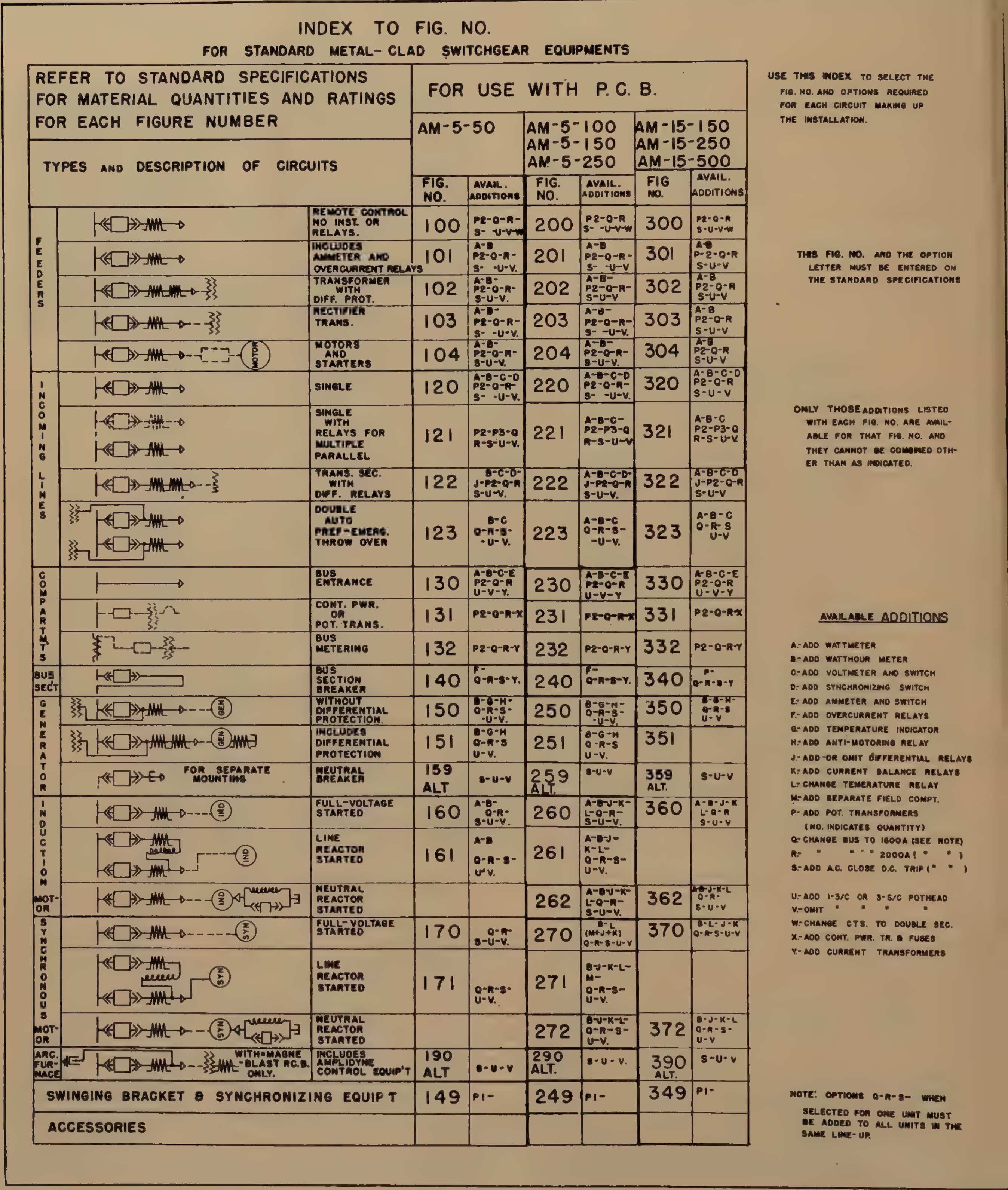


Fig. 3. A composite index summary of standard switchgear equipments. Such a summary is very useful in quickly and definitely selecting and specifying components and assemblies

INDEX TO FIG. NO.
FOR STANDARD METAL-CLAD SWITCHGEAR EQUIPMENTS

REFER TO STANDARD SPECIFICATIONS FOR MATERIAL QUANTITIES AND RATINGS FOR EACH FIGURE NUMBER

TYPES AND DESCRIPTION OF CIRCUITS			FOR USE WITH P. C. B. AM-5-50 FIG. NO.	AVAIL. ADDITIONS	AM-5-100 AM-5-150 AM-5-250 FIG. NO.	AVAIL. ADDITIONS	AM-15-150 AM-15-250 AM-15-500 FIG NO.	AVAIL. ADDITIONS
FEEDERS		REMOTE CONTROL NO INST. OR RELAYS.	100	P2-Q-R-S- -U-V-W	200	P2-Q-R S- -U-V-W	300	P2-Q-R S-U-V-W
		INCLUDES AMMETER AND OVERCURRENT RELAYS	101	A-B P2-Q-R- S- -U-V.	201	A-B P2-Q-R- S- -U-V	301	A-B P-2-Q-R S-U-V
		TRANSFORMER WITH DIFF. PROT.	102	A-B- P2-Q-R- S-U-V.	202	A-B- P2-Q-R- S-U-V	302	A-B P2-Q-R S-U-V
		RECTIFIER TRANS.	103	A-B- P2-Q-R- S- -U-V.	203	A-B- P2-Q-R- S- -U-V.	303	A-B P2-Q-R S-U-V
		MOTORS AND STARTERS	104	A-B- P2-Q-R- S-U-V.	204	A-B- P2-Q-R- S-U-V.	304	A-B P2-Q-R S-U-V
INCOMING LINES		SINGLE	120	A-B-C-D P2-Q-R- S- -U-V.	220	A-B-C-D P2-Q-R- S- -U-V.	320	A-B-C-D P2-Q-R S-U-V
		SINGLE WITH RELAYS FOR MULTIPLE PARALLEL	121	P2-P3-Q R-S-U-V.	221	A-B-C- P2-P3-Q R-S-U-V	321	A-B-C P2-P3-Q R-S-U-V
		TRANS. SEC. WITH DIFF. RELAYS	122	B-C-D- J-P2-Q-R S-U-V.	222	A-B-C-D- J-P2-Q-R S-U-V.	322	A-B-C-D J-P2-Q-R S-U-V
		DOUBLE AUTO PREF-EMERG. THROW OVER	123	B-C Q-R-S- -U-V.	223	A-B-C Q-R-S- -U-V.	323	A-B-C Q-R-S U-V
COMPARTMTS		BUS ENTRANCE	130	A-B-C-E P2-Q-R U-V-Y.	230	A-B-C-E P2-Q-R U-V-Y	330	A-B-C-E P2-Q-R U-V-Y
		CONT. PWR. OR POT. TRANS.	131	P2-Q-R-X	231	P2-Q-R-X	331	P2-Q-R-X
		BUS METERING	132	P2-Q-R-Y	232	P2-Q-R-Y	332	P2-Q-R-Y
BUS SECT		BUS SECTION BREAKER	140	F- Q-R-S-Y.	240	F- Q-R-S-Y.	340	F- Q-R-S-Y
GENERATOR		WITHOUT DIFFERENTIAL PROTECTION.	150	B-G-H- Q-R-S- -U-V.	250	B-G-H- Q-R-S- -U-V.	350	B-G-H- Q-R-S U-V
		INCLUDES DIFFERENTIAL PROTECTION	151	B-G-H Q-R-S U-V.	251	B-G-H Q-R-S U-V.	351	
	FOR SEPARATE MOUNTING	NEUTRAL BREAKER	159 ALT	S-U-V	259 ALT.	S-U-V	359 ALT.	S-U-V
INDUCTION MOTOR		FULL-VOLTAGE STARTED	160	A-B- Q-R- S-U-V.	260	A-B-J-K- L-Q-R- S-U-V.	360	A-B-J-K L-Q-R S-U-V
		LINE REACTOR STARTED	161	A-B Q-R-S- U-V.	261	A-B-J- K-L- Q-R-S- U-V.		
		NEUTRAL REACTOR STARTED			262	A-B-J-K- L-Q-R- S-U-V.	362	A-B-J-K-L Q-R- S-U-V
SYNCHRONOUS MOTOR		FULL-VOLTAGE STARTED	170	Q-R- S-U-V.	270	B-L (M+J+K) Q-R-S-U-V	370	B-L-J-K Q-R-S-U-V
		LINE REACTOR STARTED	171	Q-R-S- U-V.	271	B-J-K-L- M- Q-R-S- U-V.		
		NEUTRAL REACTOR STARTED			272	B-J-K-L- Q-R-S- U-V.	372	B-J-K-L Q-R-S- U-V
ARC. FURNACE	WITH MAGNE-BLAST RC.B. ONLY.	INCLUDES AMPLIDYNE CONTROL EQUIP'T	190 ALT	S-U-V	290 ALT.	S-U-V.	390 ALT.	S-U-V
SWINGING BRACKET & SYNCHRONIZING EQUIP'T			149	P1-	249	P1-	349	P1-
ACCESSORIES								

USE THIS INDEX TO SELECT THE FIG. NO. AND OPTIONS REQUIRED FOR EACH CIRCUIT MAKING UP THE INSTALLATION.

THIS FIG. NO. AND THE OPTION LETTER MUST BE ENTERED ON THE STANDARD SPECIFICATIONS

ONLY THOSE ADDITIONS LISTED WITH EACH FIG. NO. ARE AVAILABLE FOR THAT FIG. NO. AND THEY CANNOT BE COMBINED OTHER THAN AS INDICATED.

AVAILABLE ADDITIONS

A:- ADD WATTMETER
B:- ADD WATTHOUR METER
C:- ADD VOLTMETER AND SWITCH
D:- ADD SYNCHRONIZING SWITCH
E:- ADD AMMETER AND SWITCH
F.- ADD OVERCURRENT RELAYS
G:- ADD TEMPERATURE INDICATOR
H:- ADD ANTI-MOTORING RELAY
J.- ADD-OR OMIT DIFFERENTIAL RELAYS
K:- ADD CURRENT BALANCE RELAYS
L:- CHANGE TEMERATURE RELAY
M:- ADD SEPARATE FIELD COMPT.
P.- ADD POT. TRANSFORMERS
(NO. INDICATES QUANTITY)
Q:- CHANGE BUS TO 1600A (SEE NOTE)
R:- " " " " 2000A (" ")
S:- ADD A.C. CLOSE D.C. TRIP (" ")

U:- ADD 1-3/C OR 3-S/C POTHEAD
V.- OMIT " " " "
W:- CHANGE CTS. TO DOUBLE SEC.
X.- ADD CONT. PWR. TR. & FUSES
Y.- ADD CURRENT TRANSFORMERS

NOTE: OPTIONS Q-R-S- WHEN SELECTED FOR ONE UNIT MUST BE ADDED TO ALL UNITS IN THE SAME LINE-UP.

ments. Practically every company engaged in the generation, distribution, or utilization of electric power has set up its minimum requirements and operating practices which they feel their experience over the years has ustified on both economic and performance bases.

Examination of those company standards on an ndustry-wide basis reveals that a great variety of methods and equipments has been specified to produce dentical or very similar results. Consequently, manufacturers have been able to furnish switchgear equipments to comply with such standards only as made-to-order assemblies of standard devices. That standard equipments can be used to produce the same results was proved by our war experience. Leading manufacturers have recognized this fact and published sets of so-called "Industry Standard Equipments" which could be obtained by off-the-shelf purchasing methods.

INDUSTRY STANDARDS AND THEIR UTILIZATION

A composite index summary of such industry-standard equipments is shown in Fig. 3. An examination of the component devices (omitted here for brevity) would reveal a considerable latitude of choice in each circuit tabulation covering all of the more commonly employed functions. Each unit of these equipments is complete in itself so that when placed side by side and properly interconnected the assembled equipment is, to all intents and purposes, project-engineered in appearance and operation. A typical assembly is shown n Fig. 4, made up of standard units selected from the tabulation.

But this is only a beginning—just an attempt by the manufacturer to make switchgear equipments available in the greatest quantity in the shortest time. Whether the particular combination of equipment that was selected in Fig. 3 for a given circuit can or cannot be considered the standard for industry-wide application is not important here. The important fact is that there is some industry-wide basic pattern which can be standardized if collective efforts are applied to it. The tabulation in Fig. 3 should be considered as an outline of a pattern rather than as a completed program.

There are, of course, certain salient features of modern switchgear design which should be given careful consideration in determining the basic patterns of circuit standardization. For example, older designs using stationary circuit breakers and bare buses often made it necessary to use a circuit pattern embodying double buses and breaker by-pass switching. However, before circuits of this kind are included in any standards, consideration should be given to the factors which ormerly demanded their use.

Modern switchgear designs using removable breakers and envelope insulation may change our perspective with respect to such circuits as those just mentioned. The vulnerability and maintenance factors which dictated alternate or double-bus arrangements for an open-type structure are of negligible importance f metal-clad equipment with envelope-type insulation can be used exclusively. This consideration alone demands re-evaluation of the economics of double buses and points toward their elimination. Similarly, extra equipment needed for 100-percent service continuity (except under fault conditions) might be omitted in many cases by taking advantage of the removable-breaker feature which permits the complete substitution of a spare breaker in not more than five minutes' shutdown time, and by capitalizing the envelope-insulation feature which drastically reduces the likelihood of flashovers and insulation failures The point is that multiple-bus standardization may not be necessary to achieve maximum service continuity.

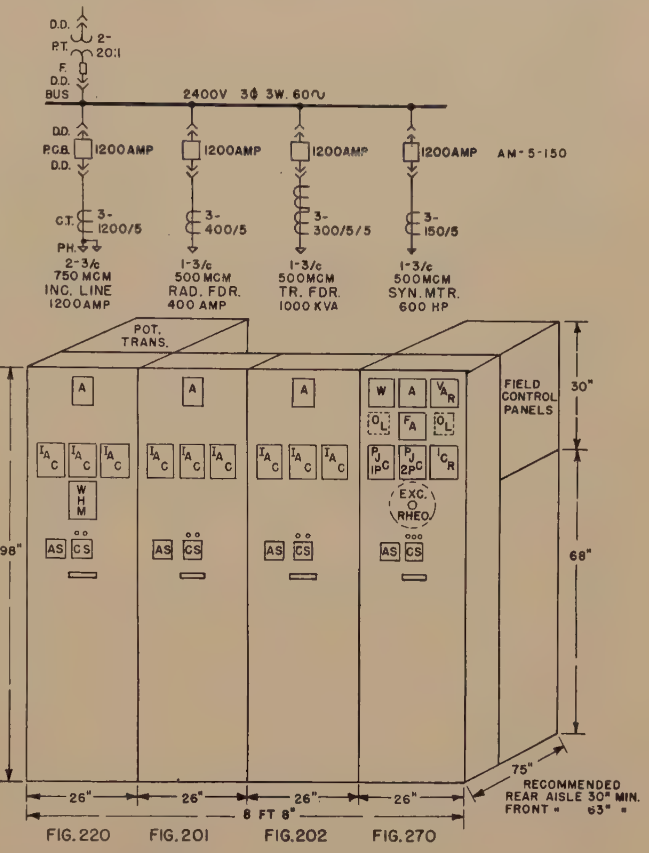


Fig. 4. An example of an Industry Standard switchgear equipment designed with the aid of the data in Fig. 3

COMPARISON OF ALTERNATIVE ARRANGEMENTS

A comparison of cost and floor space for alternative bus arrangements to obtain maximum continuity of service is shown in Fig. 5. To simplify the analysis, let it be assumed that breaker maintenance is the only obstacle to the objective of 100-percent continuity of service when using the standard simple scheme in Fig. 5(a). The following facts are then evident:

(1). Fig. 5(a) shows a scheme involving a shutdown of five minutes or less, using a spare interchangeable breaker. If this outage time is not permissible, one of the other bus schemes ranging in cost from 117 percent to 211 percent of that in Fig. 5(a) may be used. Note that minimum shutdown time results from the use of removable breakers.

An installation using fixed breakers would, in many cases, force the use of such a scheme as FIG. 5(b).

(2). FIGS. 5(c) to 5(f) show schemes which use standard metal-clad gear which can be obtained for less cost than the conventional arrangement in FIG. 5(b), though at the expense of increased floor area in some cases.

(3). FIGS. 5(c) to 5(e) show ways of accomplishing the same results but with these differences:

(a). FIG. 5(c) provides envelope insulation that is not complete because of the open switch contacts, and therefore the vulnerability of the bus is increased.

(b). FIG. 5(d) retains the envelope insulation and gives the lowest investment cost but requires increased floor space. It also retains individual feeder protection instead of placing reliance on the source breaker as does FIG. 5(c).

(c). FIG. 5(e) overcomes the floor-area objection and gives individual feeder protection, but at increased cost and with incomplete envelope insulation.

(4). FIG. 5(f) offers at a small increase in cost all the good features of FIG. 5(d) in the same floor space, plus a complete alternate bus system for flexible switching combinations.

Four conclusions can be drawn:

(1). Standardization of removable-type breaker equipment allows the choice of using minimum equipment for installations which would otherwise require more elaborate equipment of the fixed-breaker type to reduce outage time to the minimum.

(2). Wherever the avoidance of a five-minute shutdown will justify additional investment for continuity, standard metal-clad gear is the most economical as compared with an assembly like FIG. 5(b).

(3). Standardized switchgear offers the user opportunity to weigh and strike a balance among cost, insulation values, and floor area, keeping in mind that the use of a single-bus system is predicated on complete envelope insulation.

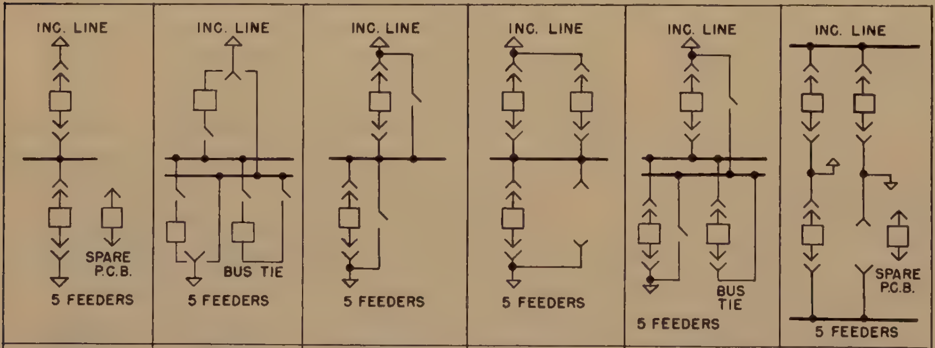
(4). Floor area can be traded for economy of investment and additional protection afforded by complete envelope insulation, plus flexibility and safety.

ECONOMIC GOALS

An improved high-quality product that can be universally applied even for the most severe operating conditions can be the goal of standardized equipment designs. There need be no sacrifice of quality for economy, even where highly favorable conditions might indicate that possibility to be warranted. Quantity production in one comprehensive design will permit manufacture of high-quality equipment at a price level comparable to, or lower than, that of inferior equipment manufactured on a made-to-order basis. Thus an improved switchgear equipment which, on a small-quantity-production basis, could be economically justified for but a few vital installations is made economically available for the entire industry. This fact alone should provide the impetus to carry forward the equipment standardization program, since it concerns every individual and organization of the electrical industry and the users of its products.

An improved product is assured because the responsibility for better performance becomes the concern of the entire industry. A channel is thereby created for the interchange of experience and ideas, individually conceived but collectively applied for the betterment of industry at large.

But lower costs, shorter delivery, and an improved product are not the only benefits to be derived, important as they are. The ease and confidence with which such units can be engineered into a distribution system should appeal to all project engineers by eliminating the mystery and individualism which have attended switchgear applications in the past. It is even possible



SINGLE BUS 6 P.C.B. POSITIONS 7 REMOVABLE P.C.B.	DOUBLE BUS 7 P.C.B. POSITIONS 7 FIXED P.C.B. 6 BY-PASS SWS.	SINGLE BUS 6 P.C.B. POSITIONS 6 REMOVABLE P.C.B. 6 BY-PASS SWS.	SINGLE BUS 12 P.C.B. POSITIONS 7 REMOVABLE P.C.B.	DOUBLE BUS 7 P.C.B. POSITIONS 7 REMOVABLE P.C.B. 6 BY-PASS SWS.	DOUBLE BUS 12 P.C.B. POSITIONS 8 REMOVABLE P.C.B.
COST 100%	COST 211%	COST 135%	COST 117%	COST 135%	COST 134%
FLOOR AREA 100%	FLOOR AREA 162%	FLOOR AREA 100%	FLOOR AREA 200%	FLOOR AREA 117%	FLOOR AREA 200%
FIG. 5(a)	FIG. 5(b)	FIG. 5(c)	FIG. 5(d)	FIG. 5(e)	FIG. 5(f)

Fig. 5. Comparison of switching schemes for maximum service continuity (exclusive of conditions causing supply-source interruption and feeder short circuits). The comparison is based on one incoming line and five feeders, and 150,000-kva interrupting capacity at 2300 volts

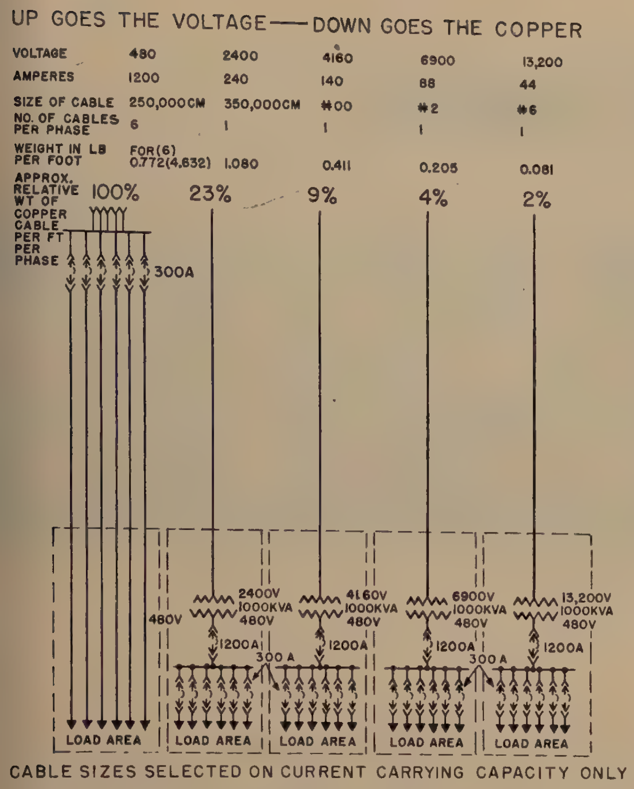

UP GOES THE VOLTAGE—DOWN GOES THE COPPER
VOLTAGE 480 2400 4160 6900 13,200
AMPERES 1200 240 140 88 44
SIZE OF CABLE 250,000CM 350,000CM #00 #2 #6
NO. OF CABLES PER PHASE 6 1 1 1 1
WEIGHT IN LB PER FOOT FOR(6) 0.772(4.632) 1.080 0.411 0.205 0.081
APPROX. RELATIVE WT OF COPPER CABLE PER FT PER PHASE 100% 23% 9% 4% 2%
300A
480V
2400V 1000KVA 480V
4160V 1000KVA 480V
6900V 1000KVA 480V
13,200V 1000KVA 480V
1200A
300 A
LOAD AREA
CABLE SIZES SELECTED ON CURRENT CARRYING CAPACITY ONLY

Fig. 6. Chart showing the extent to which high voltage lowers the material and labor costs for distribution equipment

hat standardization of switchgear equipments will utomatically bring about standardization of distribuion systems.

DVANTAGES OF TREND CONFIRMED BY EXPERIENCE IN OW-VOLTAGE EQUIPMENTS

We have already seen evidence of this trend in the ow-voltage class of equipments (600 volts and below). Not so many years ago, oil-filled transformers were laced in fireproof vaults and air-circuit-breaker switchoards were placed nearby with cables running to the oad. Short-circuits, if considered at all, were thought o be of such low values that they could be ignored. However, sad experiences and mathematical analyses ombined with tests proved otherwise, so that lowoltage air circuit breakers are now applied in accordnce with approved standards of rating and methods f determining short-circuit levels. This change in pplication standards brought about the adoption of he principle of cascading. In applications requiring nly moderate service continuity, cascading makes it ossible to provide modern breaker equipment of dequate interrupting rating and comparable in both ost and space requirement to the inadequate equipment formerly used.

Metal enclosures for safety to personnel and equipment were made available for both stationary and emovable designs. Exclusive concentration on the emovable-breaker design during the war years alowed the use of volume-production techniques in manufacture, and that has brought about hitherto unreamed-of lower prices and quantity production. In act, it has been possible to catalog such equipments so that they may be purchased and installed by people having very little or no engineering experience in such applications. Yet, the designs have not been frozen. Whenever experience under the worst conditions of service indicated that improvements were needed, such improvements were made and resulted in better breakers, smaller assemblies, and improved performance without increase in cost.

Standardization of these equipments, plus nonflammable liquid-filled or air-cooled transformers, opened the door to an entirely new concept of distribution using the load-center unit located at the load area. Very substantial economies in material and labor costs were gained by the use of high-voltage distribution to the load area and short low-voltage cable runs to the loads, as illustrated in Fig. 6.

What has been done with low-voltage equipments can be done with the higher-voltage equipments with equal or greater realization of the same type of benefits through standardization. In this field, both equipment and distribution-circuit standardizations are already well on their way and enough experience has been gained to realize that tremendous savings are more than a vision. It is very probable that no other consideration holds as much promise as does equipment standardization by *circuits*. If we can lay aside our individualism in war, why not in peace also when the results will benefit everyone directly? It can be done if we are all willing to see that it is done.

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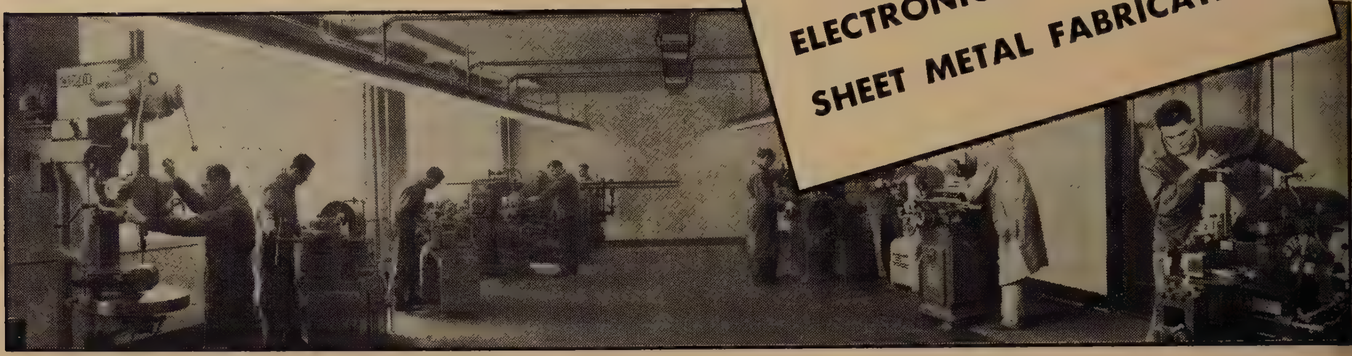

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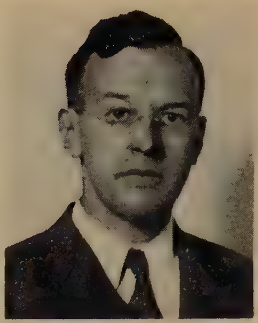
A NEW FREQUENCY-TYPE TELEMETER FOR CARRIER-CURRENT CHANNELS

Ed Lynch

H C Thomas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AN ELECTRIC telemeter is the measuring, transmitting, and receiving apparatus for remote metering by conversion of the measured quantity into a proportional separate electrical quantity for transmission. The telemeter transmitter converts the measured quantity to a separate electrical quantity for transmission, and the telemeter receiver converts the transmitted quantity to a new quantity suitable to actuate the end device. This equipment is illustrated by the typical telemeter system shown in FIG. 1.

The familiar d-c or a-c selsyns may be used advantageously for local telemetering, but because of the nature of the required transmission channel are not particularly well adapted for telemetering over the longer distances encountered in power-system applications. Two general types of telemetering can be recognized for power-system telemetering. The first is the type which utilizes pilot-wire transmission and is exemplified by the well-known torque-balance telemeter. The second type utilizes carrier-current transmission because of the distance and number of channels required.

IDEAL CHARACTERISTICS

Certain requirements must be recognized in an ideal telemetering system:

(1). For many purposes involving control, time lag must be minimized. This means that, when the measured quantity changes, there must be a change in the control-initiating signal immediately.

(2). It is also implied that systems involving discontinuous action cannot be tolerated. If these requirements are not met, the smooth, continuous, and timely action of the controller is handicapped.

(3). The accuracy and stability of a telemetering system should be the maximum consistent with an acceptable cost. Accuracy dictates that the electrical quantity which is transmitted must not be influenced by normally encountered variations in the transmission channel; the quantity must have the same or proportional magnitude at the transmitting and receiving ends. Stability of calibration and long life are highly desirable.

(4). Calibration requirements should be a minimum. Calibration must be simple and easily accomplished by the personnel and equipment normally available for such a purpose; and the requirements should not demand the attention of highly skilled and specially trained personnel.

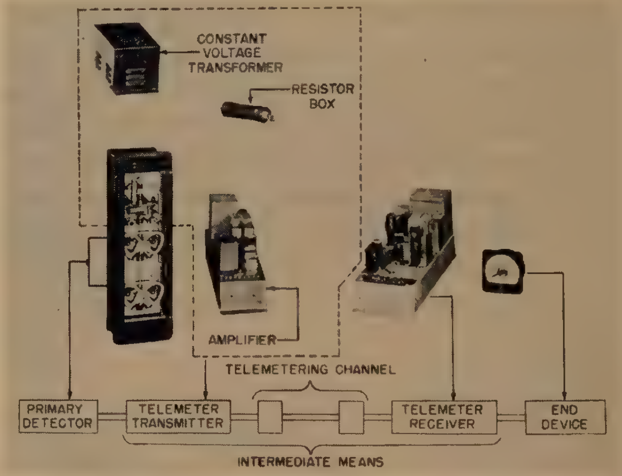

Fig. 1. The elements of a typical telemeter system shown in relation to its block diagram

(5). The telemetering system should place the minimum limitations on the carrier-current channel in the interest of flexibility of application. The required carrier-current bandwidth must be narrow, so that a maximum number of channels can be provided, with each carrier channel providing facilities for a maximum number of simultaneous measurements.

(6). Economical operation calls for minimum maintenance requirements. Ease of maintenance and freedom from trouble are important specifications.

Telemeters for use with carrier-current channels in the past have had inherent characteristics which limited their use to specific applications. Most of these

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

telemeters were of the impulse type which utilized a square-wave impulse signal the rate of which, or the duration of which, varied as the quantity to be measured changed. This resulted in an action at the receiver which was discontinuous, or at least slow, compared to rapid changes in the measured quantity. Simply increasing the rate of transmitting impulses is not a satisfactory manner of increasing the speed of response in such systems which involve "square-wave keying." This is because the faster keying rate requires increased bandwidth in the carrier-current channel and therefore reduces the number of simultaneous readings that can be transmitted.

A FASTER TELEMETER

To overcome these inherent limitations of previously available telemeters, the new frequency-type telemetering system was developed. Frequency was selected as the quantity to be recognized by the system because it is entirely independent of the transmission channel characteristics which are variable in nature. However, a sinusoidal transmitter signal, instead of the more common square-wave impulse signal, was chosen because of the reduced carrier-current bandwidth requirements. The operating-frequency range was carefully selected to provide the most desirable balance between fast time of response and carrier bandwidth requirements.

TELEMETER TRANSMITTER

FIG. 2 shows functionally the frequency-type telemeter transmitter arranged for the telemetering of watts. The primary detector (shown at the bottom of the diagram) is a watthour-meter mechanism. Standard calibration and maintenance technique will keep it in order. A disk having a serrated edge is fastened to the watthour-meter shaft. Its rotation produces a sinusoidal voltage electronically in the photoelectric pickup whose frequency varies in proportion to the measured quantity. Located above the serrated disk is a light source, and below it a photoelectric tube, arranged so that the rotation of the disk modulates the light beam directed on the tube. The shape of the serrations is such that a sinusoidal output voltage is obtained. An additional constant-torque-producing element also acts on the watthour-meter shaft so that a constant finite shaft rotation is provided when the quantity measured has zero magnitude. This can be used to provide a "zero-center" scale, and always provides a distinction between "zero input" and "inoperative transmitter." Frequencies to be transmitted with this system vary between 6 and 27 cycles per second, and are thus adaptable to transmission by practically any type of commonly used telemeter channel.

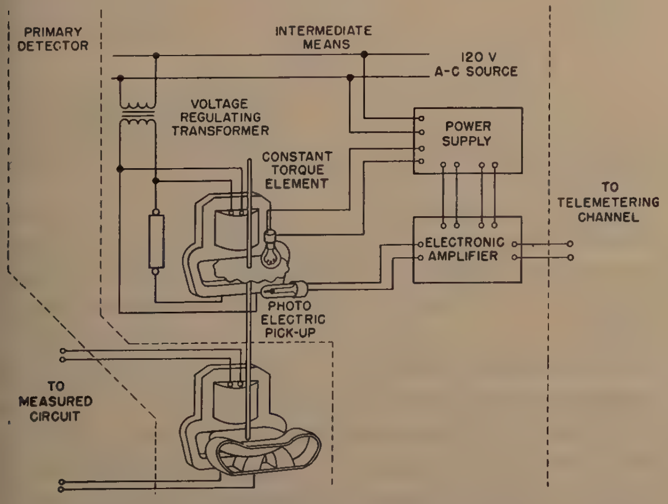

Fig. 2. Functional diagram of the frequency-type telemeter transmitter arranged for power measurements

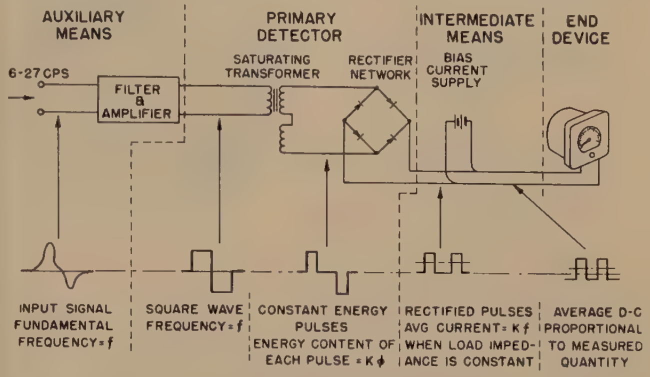
AUXILIARY MEANS
PRIMARY DETECTOR
INTERMEDIATE MEANS
END DEVICE
6-27 CPS
FILTER & AMPLIFIER
SATURATING TRANSFORMER
RECTIFIER NETWORK
BIAS CURRENT SUPPLY
INPUT SIGNAL FUNDAMENTAL FREQUENCY=f
SQUARE WAVE FREQUENCY=f
CONSTANT ENERGY PULSES ENERGY CONTENT OF EACH PULSE = Kϕ
RECTIFIED PULSES AVG CURRENT=Kf WHEN LOAD IMPEDANCE IS CONSTANT
AVERAGE D-C PROPORTIONAL TO MEASURED QUANTITY

Fig. 3. Functional diagram of the frequency-type telemeter receiver

TELEMETER RECEIVER

FIG. 3 shows a functional diagram of the frequency-type telemeter receiver, which measures the frequency of the 6 to 27 cycles per second signal in a manner not ordinarily used in frequency meters. The input signal is acted upon to eliminate interfering signals, and is changed to a square wave by the limiter-amplifier. It then excites a saturating transformer. Means are provided to insure saturation. The result, then, is a storage of a definite quantity of energy in the transformer field each half-cycle. A measurement of this energy in a given time will give a result proportional to frequency.

With a given load on the secondary of the transformer, this measurement can be accomplished, and will result in alternate positive and negative current pulses, each having a constant energy content. The average output would, of course, be zero. However, when the primary detector is completed by adding a rectifier network to the saturating transformer, the average output becomes proportional to the input frequency to the transformer, and a complete measurement operation has been performed. The milliampere output is independent of the voltage or waveshape of the input.

The stability of this receiver is dependent mainly on the properties of the transformer-core iron. Long experience has made it possible to stabilize these properties very well; thus the receiver is practically independent of the variable parameters which normally affect the operation of a frequency meter, and a high

(Concluded on next page)

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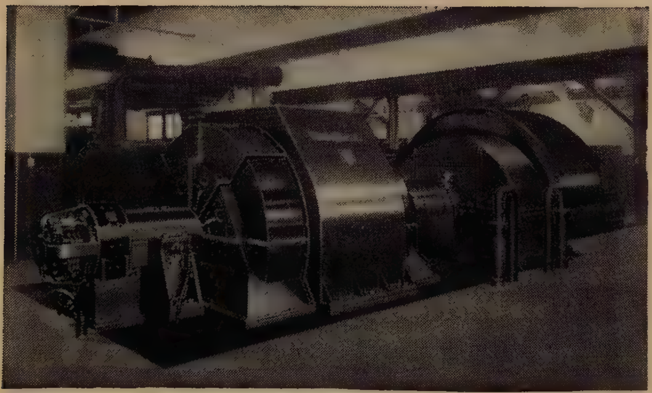

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FREQUENCY-TYPE TELEMETER

(Continued from preceding page)

degree of stability can be realized. The full-scale output of the receiver is one milliampere, and sufficient power output is available to operate directly an indicator or a recorder, or both.

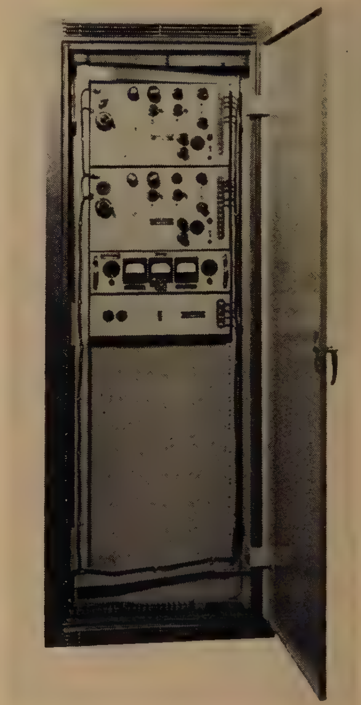


Fig. 4. Two-channel transmitter equipment through which the new frequency-type telemeter can function for remote metering or control

A review of the requirements of an ideal telemeter will show how well they are met in this new telemetering system.

(1). Response is instantaneous.

(2). Action is continuous.

(3). Accuracy and stability of calibration is high, and is inherent in the system because of the primary detectors and translating means selected.

(4). Calibration is as simple as watthour-meter calibration. Transmitter and receiver can be calibrated easily and independently.

(5). Operation is simple and the equipment is suitable for use with common types of carrier-current channels. Carrier-current bandwidth requirements for each measurement are small.

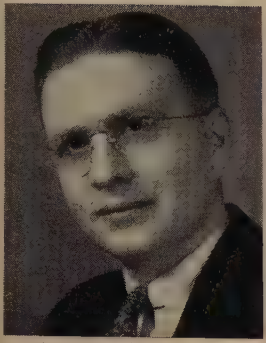
(6). The absence of contacts and electromechanical relays, and the presence of minimum moving parts, is expected to result in a minimum of maintenance.

Thus the important specifications are met. Furthermore, because of the rapid response and the continuous output signal, the system is not only suitable for remote metering, but is also eminently suitable for automatic control.

Thus the basic principles of frequency generating and measuring techniques have been refined to produce this new fast-responding frequency-type telemeter which represents a definite forward step in the art of telemetering in conjunction with modern carrier-current equipment such as that illustrated in Fig. 4.

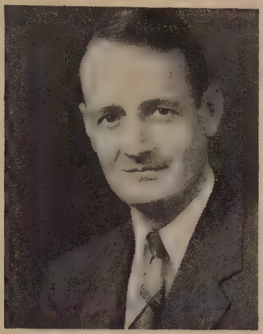
FACTORY-ASSEMBLED SUBSTATIONS: Part I

Description of various types that meet most applications and that are available for electrical utility, industrial, and power plant use



Donald E. Craig

E. M. Hunter



L. A. Madsen

By
D. E. CRAIG
E. M. HUNTER
and
L. D. MADSEN
Unit Equipment Division
Central Station Divisions,
Apparatus Department
General Electric Company

IN THE electrical utility distribution field, there are in common use a number of types of substations such as radial, primary-network, duplex, spot-network, and low-voltage-selective. Each type fulfills the needs of the particular application and is applied after such items as first cost, anticipated future expansion, voltage regulation, service continuity, and preventive maintenance, have been properly evaluated.

In general, the trend is toward simplification in the design and layout of these substations. Such features as auxiliary buses, transfer buses, breaker by-pass switches, etc., are given the acid test of—*are they necessary and are they used.* In many instances, it has been found that these additional items only complicate operation, especially in times of emergency. Furthermore, it can usually be shown that service continuity can be maintained while maintenance work is done by pole-top cutover feeder facilities located in the streets.

Various methods of voltage regulation, such as bus regulation, group feeder regulation, individual feeder regulation, and individual-phase regulation, are all now available in factory-assembled substations with the cost increasing in the order of the methods named. Bus regulation is by far the most common method used. In general, no attempts are made to maintain voltage with any of these methods during emergencies, except that the voltage spread must be limited by the maximum and minimum limits dictated by the utilization equipment. For example, overvoltages on lamps, radios, etc. can result in many unnecessary replacements; and undervoltages on such items as refrigerator motors may result in unnecessary burnouts.

For industrial applications, the load-center distribution system—having the fundamental principle of locating the substations close to the load to obtain good voltage regulation and short secondary runs of heavy copper—has had wide acceptance.

Factory-assembled load-center unit substations of radial, secondary-selective, spot-network, and secondary-network types are available. The trend is definitely toward the simple types of systems which are easily installed, easily maintained, flexible for expansion, with provisions for maintaining service in time of necessity. The most common application is the secondary-selective type of substation. Stress on adequate interrupting capacity is the keynote of all these applications.

Load-center unit substations are also being widely used to supply the auxiliaries in power plants. In general, the cascading principle of breaker application is not acceptable for these applications.

The use of the factory-assembled substation implements industrial and electrical utility expansion without incurring unnecessary lost time or wasteful expense. Specifying, procuring, and installing may be done in the shortest possible time even in the face of the existing shortage of trained and experienced personnel. The validity of this statement is shown by the fact that the popularity of these substations in the United States has increased constantly since their introduction. This is illustrated graphically in FIG. 1.

The effect of the war on the number of units in service is shown by FIG. 1 in the increased number of units from approximately 100 in 1939 to approximately 2700 in 1945. However, this trend toward factory-assembled substations has continued even after the war and the number of units that are in service now is well over 5000.

These unit substations consist of standard components which may be put together in a manner which will fit any of the standard system requirements. The various available types will permit ready procurement of a substation which will fit the fundamental requirements of many system variations. The arrangement details and the application possibilities of the various standardized factory-assembled substations now available for use on an electrical utility system, industrial

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

plants, and in power generating plants will be described in this serial.

Substation Classifications

Distribution substations may be broadly considered as two distinct classes which are determined by the low-voltage rating of the substation. These two general classifications are "primary substations" and "secondary substations." The primary substation is defined as a substation having a low voltage between 601 and 15,000 volts. The secondary substation is one having a low voltage of 600 volts or below. Factory-assembled primary substations are known as Package or Master Unit Substations and factory-assembled secondary substations as Load Center Unit Substations. All of the fundamental types of both of these classes of substations will be discussed from the standpoint of application to electrical utility and industrial services.

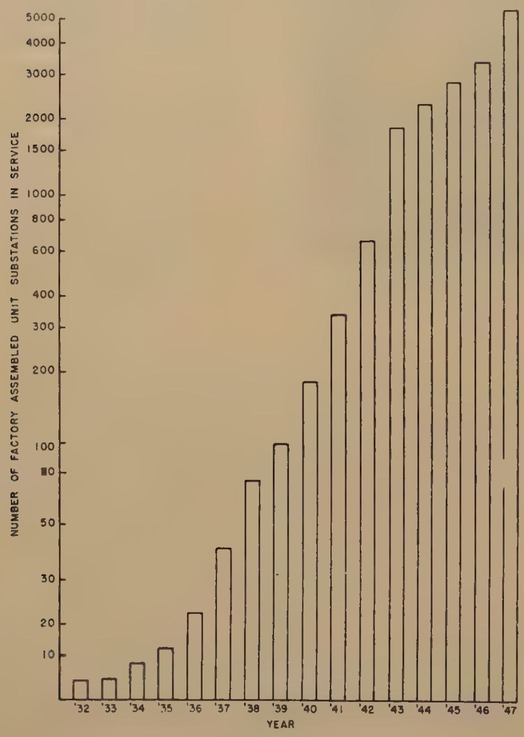

Fig. 1. Total number of factory-assembled substations in service over the fifteen-year period since their introduction. Note that the ordinate scale is logarithmic

TYPES OF PACKAGE SUBSTATIONS

Package or master unit substations provide the connecting links between transmission circuits (11 to 138 kv) and distribution circuits (2.4 to 13.8 kv). In addition to providing transforming capacity, the package substation also provides the necessary protection and control for the incoming high-voltage and outgoing low-voltage circuits. Field observation of these substations would seem to indicate that the number of possible combinations is limitless. However, there are actually only a few standard basic types into which almost all of these innumerable combinations can be classified. These are the:

(1). Radial (Fig. 2a)
(2). Primary-network (Fig. 2c)
(3). Duplex (Fig. 2d)
(4). Spot-network (Fig. 2e)
(5). Low-voltage Selective (Fig. 2f)

Each of these basic types has a functionally standardized switching scheme and general arrangement. The choice between the types depends upon the quality

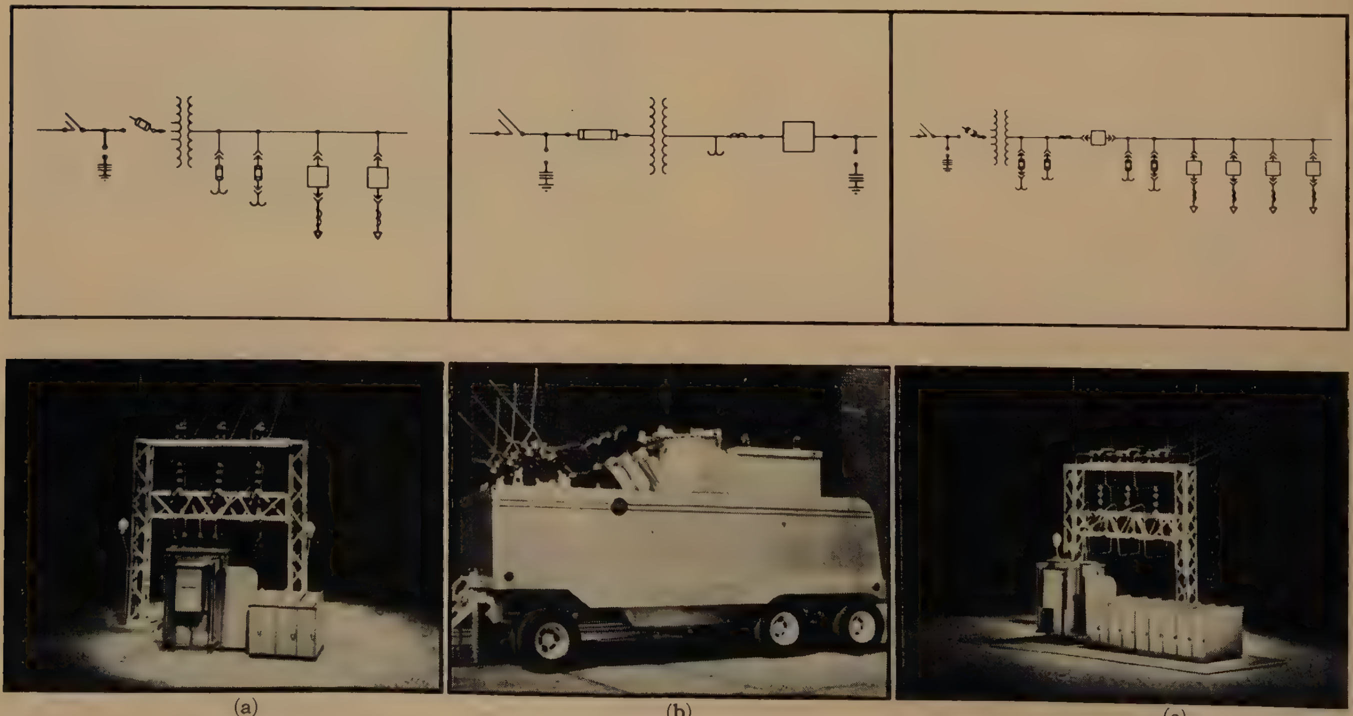
(a) (b) (c)

Fig. 2. Types of primary substations with corresponding schematic diagrams
(a). Radial (b). Mobile (c). Network

of service that it is desired to render, the system geography, and the available sources of power supply. A one-line diagram and the physical appearance of each of the five basic types of substation is shown in Fig. 2.

Radial Type

The radial substation (Fig. 2a) is characterized by a single path of power flow through the substation. The relaying in this type of substation is very simple, consisting usually of a set of overcurrent relays and a reclosing relay for each feeder. If the outgoing feeders are entirely cable rather than overhead lines, the reclosing relay is omitted. The transforming section is usually equipped with load-ratio control to give automatic voltage regulation at the bus or at some distance out on the feeders.

Protection on the high-voltage side varies, depending on a number of factors. There are three choices: an oil circuit breaker in the substation; fuses in the substation; or dependence on the transmission-line breaker back at the source. In most cases, high-voltage oil circuit breakers are not used in this type of station except where very special consideration must be given to the integrity of the transmission line. In other words, the need for using the breaker depends upon how important the transmission line is to other loads and has relatively little to do with the importance or size of the particular substation with which it is directly associated. Most substations of this type have high-voltage fuses; however, with the reliability provided by factory-assembled unit substations, it is becoming more and more common, under certain conditions, to omit the fuses and depend upon the transmission-line breaker to trip out the entire line in the remote possibility of transformer fault. In order to omit the fuses, the system loading must be such as to make it possible to set the relays on the transmission line to trip for a fault on any substation bus, and yet not trip with full load on all of the substations.

Primary-network Type

The primary-network substation illustrated in Fig. 2c is similar to the radial substation except that it has a transformer-secondary breaker designed to open on the reverse flow of power from the feeder system back into the transmission system and also provides back-up protection for the feeder circuit breakers. The same comments on high-voltage fusing apply to this type of substation as apply to the radial. The relays on the feeder circuits consist of a set of overcurrent relays and a reclosing relay. The transformer-secondary breaker is equipped with reverse-current relays and a reclosing relay which operates to close the breaker upon reappearance of voltage of correct magnitude and phase rotation at the transformer secondary.

Most primary-network units have a low voltage of 4.33 kv. The most common rating is 3000/3650 kva. Units of this size, spaced in an average manner in a primary network usually require the use of the standard 150,000-kva, 5-kv, oilless circuit breaker.

Duplex Type

The duplex substation shown in Fig. 2d is the familiar breaker-and-a-half scheme which has recently been found particularly adaptable to factory-assembled substations. As indicated in the diagram, each feeder is normally supplied by its own load-ratio-control transforming section. In case of a transformer outage or a

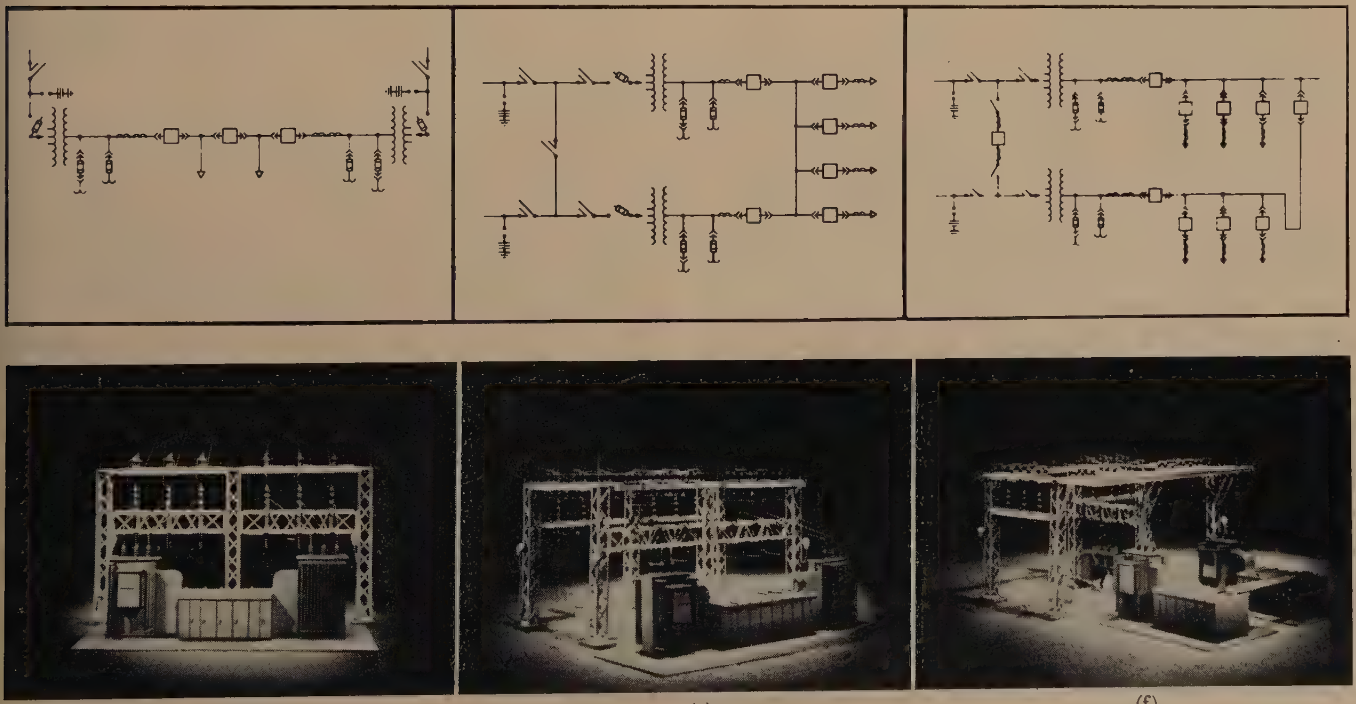
(d) (e) (f)

Fig. 2 (cont'd). Types of primary substations with corresponding schematic diagrams
(d). Duplex (e). Spot-network (f). Low-voltage selective

transmission-line failure, the combination feeder-and-transformer-secondary breaker associated with that side of the substation opens and the tie circuit breaker closes. This immediately restores service to both feeders through the remaining transformer. Usually 50,000-kva power circuit breakers are used on this type of unit for 4.33-kv feeders. The transformer sizes are so selected that, with a reasonable overload on the fan-cooled rating, one transformer can carry the simultaneous load of both feeders for a short time. Example: with two 1500-kva feeders, each transformer could be 2000/2300 kva. This would mean that one transformer, during a short-time emergency, would have to carry 3000 kva. This type of substation provides individual feeder regulation, and unusually safe by-pass facilities for circuit breakers, regulating equipment, and even the transformers themselves at relatively low cost.

Spot-network Type

The spot-network substation as shown in Fig. 2e provides a very high degree of service continuity for concentrated load areas such as a downtown low-voltage network supply or a large industrial load. In the event of a transformer or high-voltage-supply failure, the associated transformer-secondary breaker opens and load continues to be served uninterruptedly from the other transformer. Each feeder has its standardized relay complement. The secondary breakers have reverse-current and overcurrent back-up relays and voltage reclosing relays, similar to those provided in the primary network units. The feeder power circuit breakers must be large enough to interrupt the total kva of all transformers connected to the bus.

Low-voltage Selective Type

The low-voltage selective substation illustrated in Fig. 2f is similar in appearance to the spot network but entirely different in operation. The bus-tie circuit breaker is operated normally open. The transformer-secondary breakers do not have reverse-current relays, but instead are provided with undervoltage relays so that, in case of voltage failure on either bus, the transformer-secondary breaker opens and the tie-breaker closes. This restores service to both bus sections. Usually, smaller feeder circuit breakers can be used on this type of substation than on the spot network because of the fact that the tie circuit breakers are operated open thus reducing the short-circuit current. Another advantage of this type of substation over the spot network is that the two buses may be separately regulated, giving, in effect, group regulation to the short and long feeders. A disadvantage of this type compared to the spot network is the brief interruption to service on half of the feeders during the throwover operation accompanying a fault.

PACKAGE SUBSTATIONS: CENTRAL STATION APPLICATION

The availability of these five standard types of factory-assembled substations provides a systematic, simple approach to electrical utility system engineering. It can be said that almost all sub-transmission systems fall into one of *three classes*, or in some cases a combination of two of these. These are the "radial," "loop," and "multiple" transmission systems.

By considering various combinations of these three systems and the five standardized "building block" substations, it is easy to simplify a great many system studies and problems in terms of the desired continuity of service, the loads, the geography, and the cost. Comparisons can quickly be made, including or ruling out any of these factors.

Radial System

Considering first the radial subtransmission system, it is generally agreed that a radial system such as that shown in Fig. 3 using simple, single-bus, radial substations as pictured in Fig. 2a is probably the lowest-cost of all of the various kinds of power distribution systems. Naturally, this system, with its single path of power flow, is more vulnerable to troubles and interruptions than systems where some degree of duplication of subtransmission circuits and substation facilities is provided. In spite of the probability of occasional subtransmission line failures and the possibility of transformer and bus failures, there has been a marked trend in the past few years toward the simple radial system on account of its low first cost.

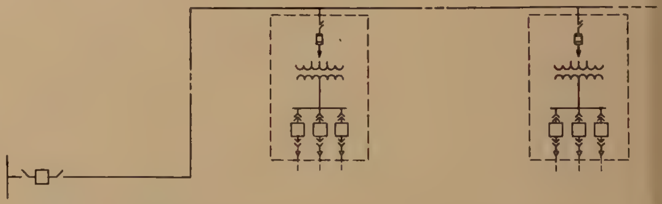
Fig. 3. Radial system, characterized by simplicity and low cost

The radial system has been made much more feasible by the advent of the high-speed mobile substation (Fig. 2b) which can quickly by-pass a complete substation as large as 5000 kva. These units have materially lessened the fear of transformer or bus failures and have greatly shortened such outages when they do occur. This practical tool also makes it possible to take advantage of the added reliability and lower cost of three-phase standard unit substations instead of single-phase transformers and open bus work, on isolated radial systems.

It is an interesting fact that for the average radial system, such as that shown in Fig. 3, one mobile substation can be paid for out of the savings which accrue from using three-phase unit substations instead of single-phase transformers with spares for *every* eight to ten substations, of ratings 750 to 5000 kva, on the system.

Another commonly used way of even further minimizing these outage times is to provide cutover faciliies at convenient locations on the feeder circuits, so hat a substation in trouble can be temporarily fed rom adjacent substations.

A pronounced trend in distribution system practice is o eliminate the use of circuit-breaker by-pass switches and transfer buses. Inexpensive pole-top group-operated disconnecting switches are often used to tie together wo feeders from a given substation, so that both can be carried on one breaker to permit opening and servicing the other breaker without dropping load.

Subtransmission line outages are, of course, much more frequent than either transformer or bus failures. However, they are usually much more easily and quicky repaired, and therefore may be tolerated if their occurrence is not too frequent. The duration of the outages can be cut down considerably by automatic reclosing features on the source-end subtransmission ine circuit breaker.

Records of subtransmission-line outages per hundred circuit miles per year are frequently kept by operating engineers. By carefully checking records of this nature with the degree of continuity of service which a given oad area justifies, it can be determined whether or not t is desirable to install a radial system, and depend upon mobile substations for emergency substation capacity, or to provide the added reliability of one of the more costly systems.

The radial system is simple, low in cost, and particularly applicable to relatively low-density load areas or small spot loads. It may be readily expanded to either a loop system or a multiple subtransmission system as oad or service continuity requirements change.

Loop System

The loop subtransmission system such as shown in FIG. 4 has many advantages for central-station applications from the practical operating point of view. For many situations it provides the lowest-cost way of serving a given substation or several substations from two separate sources. A rather high degree of reliability is possible because these two separate sources are usually over two completely different paths and are thus not subject to the same local disturbances, such as lightning, fires, tornadoes, etc. The generally ower cost of the single looping circuit as compared to a two-circuit subtransmission system is offset somewhat by the cost of an additional circuit breaker required at each substation and sometimes by more complicated relaying requirements.

FIG. 4a shows a loop subtransmission system using a duplex substation. This combines the features of the loop circuit with the individual feeder regulation and by-pass facilities of a duplex unit substation. The diagram shows that if a subtransmission line failure occurs at *X*, the high-voltage breaker at the substation opens, the adjacent transformer-secondary breaker opens, and the bus-tie breaker closes, thus continuing service on all feeders from the good end of the loop circuit. This complete throw-over operation akes less than two seconds, during which time there is a brief outage to one-half of the feeders. The duplex substation can be used to supply a minimum of two feeders and can be expanded in any multiple of two feeders. A number of system studies have shown that where individual feeder regulation and two sources of power are desired, this loop subtransmission duplex substation scheme is one of the lowest in cost. A comparison of the cost of a standard duplex substation used in a loop system with an older field-assembled substation will be shown later in this serial.

FIG. 4b illustrates a spot network unit as used on a loop subtransmission system.

When a subtransmission line failure occurs with this arrangement, the high-voltage breaker opens and a reverse-current relay on the adjacent transformer secondary breaker operates, leaving all the feeders fed through the remaining transformer. This provides for the continuous service that is required for some applications and eliminates even a momentary interruption.

It is common practice not to have 100-percent reserve transformer capacity on these double-ended units. In most cases it is customary to utilize the fan-rating of the transformers plus a reasonable degree of overloading for times when one transformer may be out of service.

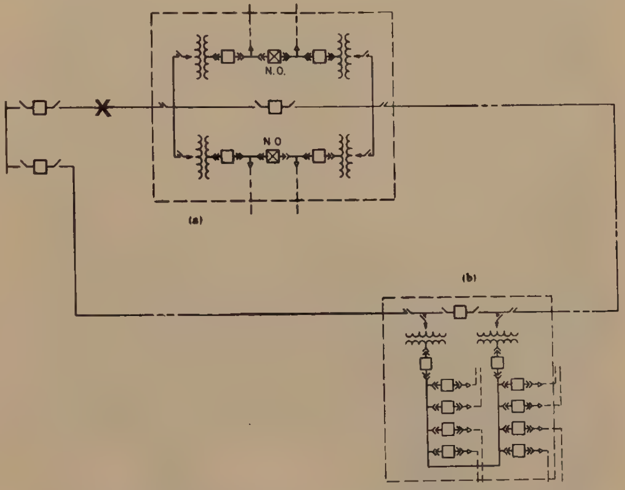

Fig. 4. Loop system permits low-cost service from two separate sources
(a). With duplex substation (b). With spot-network unit

The loop subtransmission—low-voltage selective arrangement is a rather frequent combination. As indicated in FIG. 2f, the low-voltage selective scheme provides a bus-tie breaker which is normally open but has the same high-voltage arrangement as for the spot network.

Multiple System

The multiple subtransmission system (FIG. 5) is characterized by two or more circuits over the same or different rights-of-way. It is generally simpler to operate and relay than the loop system and may be more or less expensive depending upon the number of ratings of the substations.

(Continued on next page)

FACTORY-ASSEMBLED SUBSTATIONS

(Continued from preceding page)

Fig. 5a illustrates a multiple subtransmission-duplex substation arrangement which uses relatively inexpensive fuses as protection for the subtransmission circuit against transformer failures. A multiple subtransmission system using duplex units is very flexible, in that single duplex units may be originally located near the centers of each load area. When certain loads grow, additional duplex units can be added as building blocks exactly when and where they are needed. This procedure keeps the system investment very closely in line with the actual load requirements.

The multiple subtransmission—low-voltage selective system shown in Fig. 5b offers an economical arrangement for large substations (10,000- to 20,000-kva) in dense load areas by using group feeder regulation. High-voltage oil circuit breakers are used to isolat subtransmission line faults. Fuses or oil circuit breaker are used to protect the continuity of service of the res of the station against transformer failures. For thi purpose, each of the three units normally operates wit its bus-tie breaker open and with its load-ratio contro set for a slightly different bus voltage. Feeders ar grouped according to their length or characteristics on the three units and thus considerably bette voltage regulation is given each feeder than would b given with all feeders at the same voltage on a soli bus. It should be understood, however, that durin emergencies or maintenance periods, the bus-ti breakers are closed, thereby causing all feeders to b fed at the same voltage.

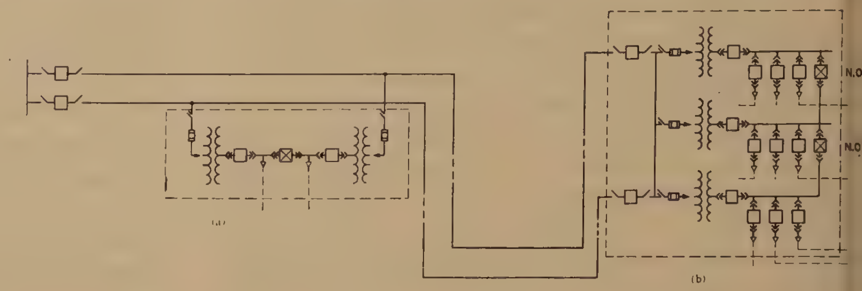

Fig. 5. Multiple subtransmission system provides more than one circuit and is simple to operate
(a). With fuse protection
(b). With group feeder regulation

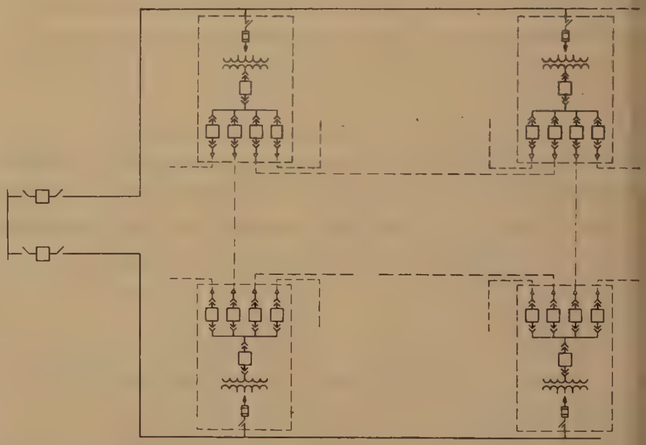

Fig. 6. Primary-network unit substation affords maximum over-all service continuity

A variation of the multiple subtransmission syste uses primary-network unit substations. As indicated i Fig. 6, the transformer secondary breaker opens o reverse current in the event of subtransmission line o transformer failure. This type of system is usually applied in light- and medium-density load areas of 100 to 9000 kva per square mile and affords the maximu of over-all service continuity, at the same time avoidin any need of individual feeder regulation. Its cost i often less than any other type of system that provide an equivalent degree of continuity of service and voltage regulation.

Since the war there has been considerable extensio of the primary-network idea, both in adding to existin networks and in starting new ones.

(To be continued)

Below: Dust cover removed, showing details.

Left: Clarostat composition-element control.

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part III

Atmospheres for preventing or reducing oxides, with emphasis on their uses and properties, costs, and methods of manufacture and distribution

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

TYPICAL protective atmospheres used in industry were listed in Part I*, Table I. Most of those listed are used for preventing oxidation, although sometimes a few of them are used for reducing oxides. Descriptions of these atmospheres follow, with emphasis on their uses, properties (Table V), costs, and methods of manufacture and distribution.

HYDROGEN

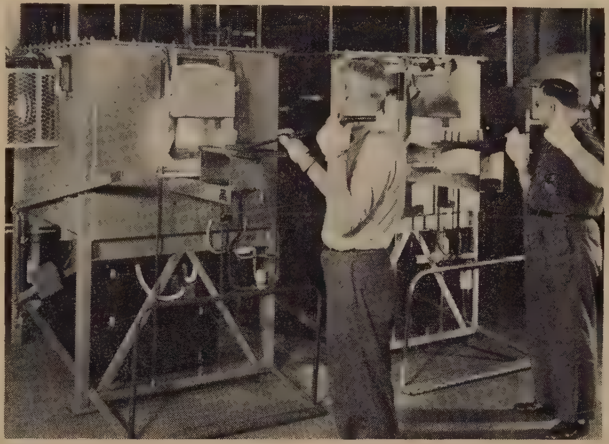
One of the first atmospheres used both for preventing oxidation and for reducing oxides was hydrogen, and it is still used to a considerable extent. It is especially valuable in furnace applications such as for the annealing of silicon iron; for the furnace-brazing of a variety of types of material; for the sintering of various pressed-powder compacts; and for the annealing and reducing of metal powders in manufacture. In other fields, it is used for sodium-hydride descaling; atomic-hydrogen welding; and hydrogenization of oils, fats, lards, etc. Hydrogen atmospheres are commonly used in furnaces of various types such as the box, bell, elevator, mesh-belt-conveyor, and roller-hearth-conveyor types.

PROPERTIES OF HYDROGEN

Hydrogen is highly reducing on oxides of various metals, such as iron and copper, at elevated temperatures. This property, combined with its ready availability, has been largely responsible for its wide use. The reducing property of hydrogen on iron oxide was emphasized in Part II* by Equations (11) and (12), by FIG. 10, and by the related text.

This reducing effect of hydrogen, although ordinarily desirable, is sometimes a disadvantage; for example, some commercial grades of copper contain small amounts of copper oxides at the grain boundaries, which for many applications are permissible or desirable. During the annealing of such copper at elevated temperatures, however, hydrogen will reduce the oxides and form tiny pockets of steam in which extremely high pressures are developed. As a result, rupturing takes place along the grain boundaries, the over-all effect of which is the embrittlement of the copper. This leaves two alternatives: either the copper must be annealed in an inert atmosphere containing little or no hydrogen; or the specifications of the copper must be changed to eliminate the oxides in it, if hydrogen or hydrogen-bearing atmospheres are to be used in the annealing or other treatments.

Hydrogen is generally accompanied by certain impurities. For many applications, this is unimportant and the gas is usable as received. In other instances, however, it is desirable or necessary to remove the impurities when critical operations are being performed. This subject will be presented later under "Purification." Different types of impurities are encountered in hydrogen made by various methods. A typical example is where oxygen-free dried hydrogen containing carbon monoxide and/or methane may carburize alloy retorts and the work at elevated furnace temperatures, or leave carbon deposits on the retort walls and on the work.



Two small box-type electric copper-brazing furnaces using hydrogen as protective atmosphere

Hydrogen is very inflammable, having an extremely high rate of flame propagation. Its ignition temperature is 1020 to 1120 F when mixed with air or oxygen. Experimenters report the producing of pressures up to 100 to 120 psi with hydrogen-air mixtures, the actual pressure depending on the relative proportions of hydrogen and air. The explosive range when mixed with air is from about 4 to 74 percent hydrogen, or from about 4 to 96 percent hydrogen when mixed with oxygen. Although this explosive property requires that hydrogen be handled with respect, it should be stated that hydrogen has been used in large production furnaces for at least thirty years with an enviable safety record.

It is common to compress hydrogen into bottles for distribution, at which time most of the moisture is condensed out. A small amount of moisture may carry over from the pumps, however, and collect in the bottoms of the bottles; for example, the dew point of bottled hydrogen at 1800-lb pressure is about −30 F. This dew point gradually increases as the pressure

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*Part I appeared in the November, 1948, issue; Part II in December.—ED.

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

decreases during consumption of the hydrogen, reaching −10 F to +20 F at 100-lb pressure.

Hydrogen is very light in weight—in fact, it is the lightest element known. It has only one-fifteenth the weight of air, its specific gravity being only 0.069 as compared with 1.0 for air. Thus, hydrogen is easily displaced by air and rushes out of the top of furnace door openings rapidly when free to do so. Similarly, it has a tendency to linger in the tops of open furnaces which are not completely purged or burned out, a factor to consider from the safety angle when making repairs.

Because of its high rate of flame propagation, hydrogen burns with a short, hot flame immediately upon contact with air. The flame is an almost colorless blue. The thermal content of hydrogen is 325 Btu as compared with 540 for city gas and 1000 for natural gas. Consequently, hydrogen not only produces considerable heat as it escapes from door openings of furnaces, but the heat is localized at the door openings. These are not important factors for small furnaces but they are for large furnaces using great quantities of the gas. The heat must not only be dissipated from the locality, but the doors and door frames must be built to withstand the heat.

Hydrogen is an excellent heat conductor, its thermal conductivity being 7.01 as compared with 1.0 for air. This means that hydrogen serves to accelerate both the heating and cooling rates of the work in furnaces. Thi property is of particular advantage when rapid cooling of the work is desired to produce certain physica properties, inasmuch as hydrogen is capable of removing heat from the work seven times as fast as air.

The high thermal conductivity of hydrogen also affects the thermal losses in furnaces because of high convection and conduction losses, both into the cooling chamber and through the insulating walls of the heating chamber. A pronounced effect of hydrogen on the wall losses of a box-type heat-treating furnace is graphically demonstrated in Fig. 15. In this chart, the wall losses are plotted against temperature, using atmospheres containing three different percentages of hydrogen, and also using air, all at a flow of 250 cfh entering the furnace. For comparison, a fifth curve is added at the bottom, using dead air in the furnace. The atmospheres containing these various amounts of hydrogen were about the same as those listed in Part I, Table II, item A1a, unpurified hydrogen; F1a, endothermically reacted fuel gas with air; and E1a, partially combusted fuel gas, respectively.

Fig. 15 shows that at 1800 F losses with flowing air were 10.6 kw hr per hour, with 16 percent H_2 11.8, with 40 percent hydrogen 13.1, and with 100 percent hydrogen 17.5 kw hr per hour. Thus the change from air to 100 percent hydrogen produced an increase of 72

TABLE V

PROPERTIES OF GASES USED FOR PROTECTIVE ATMOSPHERES*

Gas	Specific Gravity	Thermal Conductivity Relative to Air	Btu Content
A. Hydrogen	0.069	7.01	325
B. Nitrogen	0.972	0.999	0
C. Carbon dioxide	1.527	0.590	0
D. Dissociated ammonia			
(1). Untreated	0.295	5.507	244
(2). Burned with air			
(a). Partially burned	0.755	2.442	78
(b). Completely burned	0.963	1.059	3
E. Combusted fuel gas			
(1). Unpurified			
(a). Partially burned	0.858	1.878	96
(b). Completely burned	1.030	0.994	5
(2). Purified			
(a). Partially burned			
I. CO_2-free and dry (Neutralene)	0.825	1.929	99
(b). Nearly completely burned			
I. CO_2-free and dry (Neutralene)	0.954	1.118	14
(c). Completely burned			
I. CO_2-free and dry (Neutralene)	0.966	1.041	5
F. Reacted fuel gas			
(1). With air over catalyst			
(a). Completely reacted	0.622	3.228	200
G. Carbon monoxide	0.968	0.959	322
H. Methane	0.554	1.127	1013
J. Air	1.000	1.000	0

* For analyses of gases A to F inclusive, see Table I, Part I.

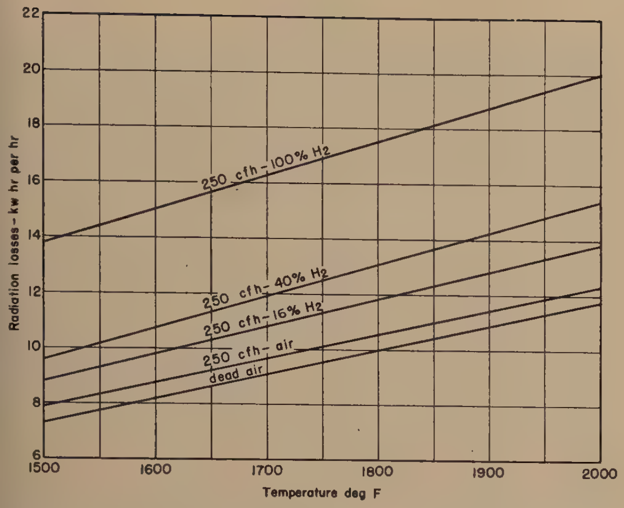


Fig. 15. **Effects of hydrogen atmospheres on radiation losses of box-type electric furnace**

percent in thermal losses; air to combusted gas 11 percent; and combusted gas (16 percent H_2) to endothermically treated gas (40 percent H_2) 11 percent. These data indicate that the hydrogen content of a furnace atmosphere has a direct influence on the operating cost, a point to be considered when selecting the best atmosphere for the job.

COST

The cost of hydrogen depends on the methods of manufacture and distribution, and whether its by-products, such as oxygen, are also marketed. For example, an electrolytic plant consumes about 150 kw-hr and a small amount of distilled water to produce 1000 cu ft of hydrogen, with a total material cost of about $1.55 as listed in Table I. At this cost, there would also be produced 500 cu ft of oxygen, which if used or sold would reduce the effective hydrogen cost. If hydrogen is purchased in bottles, its price varies from $6 to $12 per M cu ft (delivered) measured at atmospheric pressure. Less expensive gases than hydrogen are commonly used wherever practicable but, in spite of the cost factor, hydrogen is effectively and widely used in from small to rather large hourly requirements varying from 2 cfh to 4000 cfh or more per furnace.

MANUFACTURE

Hydrogen for industrial purposes is made in a variety of ways, the most common of which are:

(1). Electrolysis of distilled water
(2). Electrolysis of sodium-chloride solution
(3). Catalytic process for converting hydrocarbons
(4). Catalytic process for converting water gas
(5). Iron-contact process

All of these methods give good results, and the choice is largely determined by the economics and accessibility of various materials or power and possible markets for by-products produced. Each method introduces certain impurities in the hydrogen, which may or may not be troublesome in protective atmospheres. If objectionable, the impurities might have to be removed, or hydrogen made by some other method might be preferable.

(1). Hydrogen made by electrolysis of distilled water
  (A). Process
    (I). Electric current passes through electrolyte in cell, causing hydrogen to collect at one electrode and oxygen at the other
      (a). Electrolyte is either sodium hydroxide or potassium hydroxide in distilled water
  (B). By-product
    (I). Oxygen gas
  (C). Possible impurities
    (I). Carbon dioxide—slight trace from air
    (II). Oxygen—0.1 to 0.3 percent, depending on condition of cells
    (III). Water vapor—saturated (at cells)
    (IV). Oil—traces carried over from compressor, including any impurities in oil, such as sulfur

(2). Hydrogen made by electrolysis of sodium-chloride solution
  (A). Process
    (I). Electric current passes through sodium-chloride solution in cell, causing hydrogen to collect at one electrode and chlorine at the other, and the formation of sodium hydroxide in the electrolyte
  (B). By-products
    (I). Chlorine gas
    (II). Sodium hydroxide. (Actually, sodium hydroxide or caustic soda is usually the major product and hydrogen a by-product)
  (C). Possible impurities
    (I). Oxygen—up to 0.1 percent
    (II). Nitrogen—up to 0.2 percent
    (III). Water vapor—saturated (at cells)
    (IV). Oil from compressor—traces

(3). Catalytic process for converting hydrocarbons
  (A). Process
    (I). Hydrocarbon gas, such as natural gas, propane, or butane, is mixed with steam, heated, and passed through a catalyst to produce $H_2 + CO$ and a small amount of CO_2.
    (II). Mixture of $H_2 + CO + CO_2$ with steam is passed through a catalyst to convert CO to CO_2, during which operation there is produced an additional volume of H_2 equal to that of the CO
    (III). Mixture of $H_2 + CO_2$ is passed through a chemical absorbing tower, which absorbs CO_2 and reduces it to 0.0 percent, leaving hydrogen and a slight amount of CO as an impurity
  (B). By-product
    (I). Carbon dioxide, which is subsequently driven out of absorbing liquid in a reactivating tower by means of heat
  (C). Possible impurities
    (I). Carbon monoxide—from a trace up to 0.5 percent

        - (II). Methane—from a trace up to 0.5 percent (sometimes available as an alternative to carbon monoxide)
        - (III). Water vapor—saturated
        - (IV). Oil from compressor—traces
- (4). Catalytic process for converting water gas
    - (A). Process
        - (I). Water gas (H_2 + CO + small amounts of CO_2, N_2, and CH_4) is made by passing steam through hot coke
        - (II). Same as 3AII and 3AIII
    - (B). By-product
        - (I). Same as 3BI
    - (C). Impurities
        - (I). Same as 3CI, 3CII, 3CIII, and 3CIV
- (5). Hydrogen made by the iron-contact process
    - (A). Process
        - (I). Water gas (H_2 + CO + small amounts of CO_2, N_2, and CH_4) is made by passing steam through hot coke
        - (II). Water gas and air are partially burned through a tower containing trays of iron oxide; this heats the oxide and reduces it to iron. When the oxide is fully reduced, the flow is shut off and steam is passed through the reduced iron, which produces hydrogen and iron oxides
    - (B). Possible impurities (dependent on choice between two types of plants)
        - (I). From low-purity plant (98-99.5 percent H_2)
            - (a). Carbon monoxide—0.5 percent
            - (b). Methane and nitrogen—total 0.5 percent
            - (c). Oil from compressor—traces
        - (II). From high-purity plant (99.7-99.9 percent H_2). Includes a catalyst-purification step added to low-purity plant to remove CO
            - (a). Methane and nitrogen—total 0.3 percent or less
            - (b). Oil from compressor—traces

DISTRIBUTION

Hydrogen made by all of the foregoing methods is commonly distributed in one or both of the following ways:

(1). Collected in holders, and compressed to about 15 psi, or compressed into cylinders up to 400 psi or into large heavy-walled tubes up to 2400 psi. It is then distributed through lines in the immediate vicinity

(2). Collected in holders, compressed into bottles, and trucked or shipped to destination. Small quantities are supplied at 2000 psi in steel bottles which contain 193 cu ft of hydrogen measured at atmospheric pressure and 68 F. Banks of about 12 interconnected cylinders on portable dollies, containing about 3200 cu ft total, afford convenient handling for larger supplies. For greater requirements, trailers are used as shown in Fig. 16 containing a total of 28,600 cu ft of hydrogen in 22 steel tubes at 2400 psi. Available, if needed, are even larger trailers and railroad cars carrying up to 200,000 cu ft per car.

NITROGEN

Nitrogen, being inert, is sometimes used for purging furnaces preceding and following the use of inflammable atmospheres, as a safety precaution. It is also employed for strain-relief annealing of silicon iron. When purified, it could be used for bright-annealing copper wire, but less expensive gases are usually selected. Another use for nitrogen is in the bubbling of synthetic resins during cooking, and it is an excellent gas for stand-by purposes to protect against failure of some other gas supply, such as hydrogen. For the latter use, the nitrogen is automatically switched over; the details of this method will be given in a later part of this serial.

PROPERTIES OF NITROGEN

Under most conditions, molecular nitrogen is inert to materials being treated, and normally it has no noticeable effect on iron, copper, or other common metals. However, there are certain elements with which nitrogen combines at elevated temperatures to form nitrides which are commonly hard and brittle, thus lacking ductility and tensile strength which may be objectionable. Molybdenum, chromium, titanium, and columbium are typical metals so affected by nitrogen.

Nitrogen from an air liquefaction and rectification plant commonly has an analysis of about 99.8 percent N_2, 0.2 percent O_2, and it is saturated with water vapor. If it is compressed into bottles, however, the dew point drops to about −30 to −10 F. If it is necessary to remove the oxygen from the nitrogen, this can be done, as will be explained later under "Purification."

Nitrogen weighs about the same as air, having a specific gravity of 0.972. Its thermal conductivity also is about the same as that of air, being 0.999 compared with 1.0 for air.

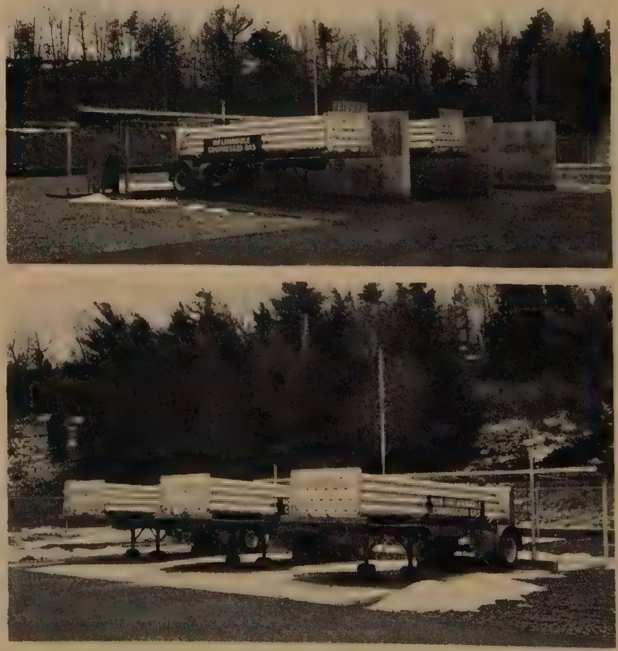


Fig. 16. Examples of trailer delivery of large quantities of gases in tubes to the point of use. (*Above*) Hydrogen, because of its inflammability, is placed between barriers. (*Below*) Loads of nitrogen are simply backed into place and connected into the discharging equipment

OST

The cost of unpurified nitrogen in pipelines from an ir liquefaction and rectification plant, including ma-erials only, is about 50¢ per M cu ft. When purchased n bottles under pressure, the price is about $8 to $10 er M cu ft as delivered, as measured at atmospheric ressure.

Purification of nitrogen to remove the oxygen costs ery little. In large plants where nitrogen in pipelines an be purified by adding hydrogen from pipelines, the ost of materials for purification is about 4¢ per M, naking the total 54¢ per M. When bottled purified itrogen is purchased, with perhaps bottled hydrogen eing used in the purifying operation, and the cost of nixing, extra equipment, and other items factored in, he purchase price is in the range of $12 to $14 per M.

IANUFACTURE

Nitrogen is principally made for industrial purposes y the liquefaction and rectification of air

(A). Process
  (I). Air is compressed at 100 to 800 lb operating pressure to produce liquid air
  (II). Liquid air is then separated into its components by repeated liquefaction and evaporation to produce nitrogen vapor plus oxygen liquid, or nitrogen vapor plus oxygen vapor
(B). By-product
  (I). Oxygen gas
(C). Impurities
  (I). Oxygen—0.1 to 0.5 percent
  (II). Argon—trace
  (III). Water vapor—bone dry (dew point −180 C) as taken from the liquefaction plant, or saturated if collected in a holder
  (IV). Oil from compressor—traces (oilless nitrogen can be obtained if specified)

ISTRIBUTION

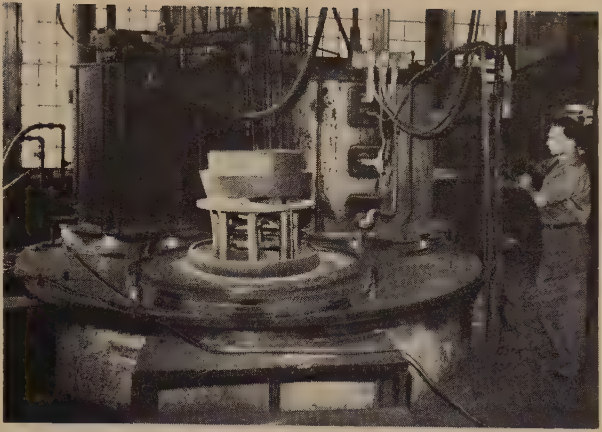
Nitrogen is stored and distributed in the same general vays which were previously described for hydrogen.

Carbon Dioxide

Carbon dioxide is useful for protective atmospheres n industry. Some applications are the bubbling of ynthetic resins, purging and protecting paints in torage tanks and lines, fire prevention and fire extin-uishing, and as a nonoxidizing atmosphere in oil-filled ransformers and cables. But in many of these instances, ombusted hydrocarbon gases serve equally well, at nuch lower cost. Dew-point potentiometers for measur-ng moisture content of gases commonly employ carbon ioxide for chilling the mirror on which a film of dew s deposited at the dew point of the gas being measured.

ROPERTIES OF CARBON DIOXIDE

Carbon dioxide is inert to many materials such as opper, paint, varnishes, and resins. Thus, these ma-erials do not oxidize in CO_2 protective atmospheres. arbon dioxide does oxidize iron at elevated temperatures*, however, as well as numerous alloying elements such as chromium, manganese, vanadium, silicon, aluminum, and zinc.



A bell-type three-stage copper-brazing furnace using hydrogen atmosphere. Heating chamber (right); cooling chamber (left)

Impurities found in carbon dioxide are generally only oxygen and nitrogen, but these are so low that the gas can often be used without considering the purity. Tests on carbon dioxide have shown the impurities totalling from 0.0 to 0.3 percent. When impurities have been found, they have ranged up to 0.06 percent oxygen and 0.24 percent nitrogen. The moisture content of carbon dioxide, whether purchased in dry ice or liquid form, ordinarily is 0.3 to 1.0 mg per liter, which is the equivalent of −30 to −5 F dew point.

Carbon dioxide differs from most other gases in that it is very much heavier than air, its specific gravity being 1.527. Thus, when it is released into the air, it spreads over the floor and other low areas. This characteristic makes it useful for smothering and extinguishing fires of highly inflammable liquids.

On the other hand, the thermal conductivity of carbon dioxide relative to air is low, being only 0.590.

COST

A typical price of carbon dioxide bought in the form of dry ice is 4¢ per lb. When vaporized, the carbon-dioxide-gas cost becomes $4.65 per M cu ft. If purchased in bottles in liquid form, a representative price is 8¢ per lb, or $9.30 per M cu ft. These prices vary, however, according to the distribution points, and in some localities they are considerably different from the prices given here.

MANUFACTURE

Carbon dioxide is principally made by the combustion of coke; but it sometimes is available as a by-product, such as in the catalytic processes for making hydrogen previously described, or by absorption from flue gas in power plants. In all of these methods, CO_2 is discharged from absorbing chemicals during the reactivating cycle. Also, the beverage industries sometimes produce and sell by-product CO_2 from malts, etc.

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*See Fig. 10 in Part II.

In this instance, there are sometimes odors in the gas which may need to be removed.

- (1). Carbon dioxide from combustion of coke
  - (A). Process
    - (I). Coke is burned in a specially constructed boiler to produce mainly $CO_2 + N_2$
    - (II). CO_2 is scrubbed out by chemical absorption method
    - (III). CO_2 is driven out of absorbent by heat
      - (a). CO_2 is then compressed and liquefied, and charged into bottles
      - (b). Or CO_2 is compressed and the gas is expanded into snow, compressed into solid dry ice, and put into cartons
  - (B). Impurities
    - (I). Oxygen—0.0 to 0.06 percent
    - (II). Nitrogen—0.0 to 0.24 percent
    - (III). Water vapor—0.3 to 1.0 mg per liter, equivalent to dew point of −30 to −5 F
    - (IV). Oil from compressor—traces

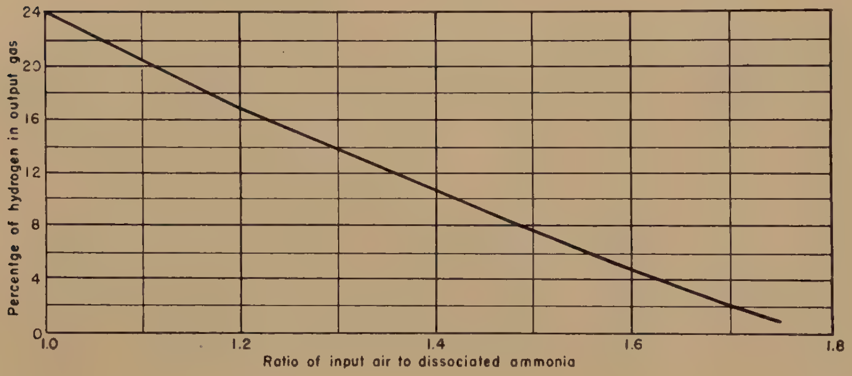


Fig. 17. **Effects upon hydrogen content when burning dissociated ammonia at various air-gas ratios**

DISTRIBUTION

Carbon dioxide for protective atmospheres normally is distributed both in the liquid form in bottles and as dry ice in cartons. For the latter method, the user puts several cakes of dry ice into a gas-tight metal container and draws gas from the container the same way it is drawn from bottles of liquid CO_2. For both methods the pressure is about 850 psi at 70 F, or 1280 psi at 100 F. One pound of CO_2 in either form produces about 8.8 cu ft of gas.

Dissociated Ammonia

Dissociated ammonia is being used successfully in many applications as a low-cost substitute for hydrogen, particularly for furnace atmospheres, atomic-hydrogen welding, and sodium-hydride descaling. Used as furnace atmospheres, it protects coils of carbon-steel strip, retaining their bright surface finish with minimum surface decarburization, in bell-type furnaces. It is also effective for bright-annealing, bright-hardening, and copper-brazing high-chromium alloys, such as stainless steel, which are protected in metal retorts within furnaces to maintain the high purity of the dissociated-ammonia atmospheres. Thus, it can be used for many applications for which hydrogen is suitable. There are a few limitations, however, where molecular nitrogen is undesirable, in which instance the use of dissociated ammonia should be avoided; for example, when sintering compacts made of stainless-steel powders containing small percentages of titanium or columbium, or compacts made of molybdenum powders, as explained under "Properties of Nitrogen."

Typical steels which are welded by the atomic-hydrogen process using dissociated ammonia are low-carbon, medium-carbon, and 18-8 stainless steels. Savings through use of dissociated ammonia become attractive when the hydrogen consumed is at least 50 cfh. About 25 percent more dissociated ammonia is required than bottled hydrogen for adequate protection of the electrodes and the work. At currents above 125 amp, the tungsten welding electrodes are dissipated more slowly with hydrogen than with dissociated ammonia.

PROPERTIES OF DISSOCIATED AMMONIA

Dissociated ammonia, like hydrogen, is highly reducing on ferrous and nonferrous oxides. It consists of about 75 percent hydrogen and 25 percent nitrogen. Normally, the cracking of the ammonia (NH_3) is 99.95 percent complete or better. Thus, there is only a trace of ammonia in the gas, 0.0 percent oxygen, and the dew point is about −60 F.

Dissociated ammonia is highly inflammable because of its hydrogen content. It is less than a third as heavy as air, its specific gravity being 0.295. Its thermal conductivity relative to air is 5.507.

Should the small amount of undissociated ammonia in the gas be objectionable, all traces can be removed by passing the gas through activated alumina. Ammonia scrubbers are commercially available for this purpose.

COST

The cost of dissociated ammonia largely depends on the delivered price of the liquid ammonia consumed, which in turn is related to the location from distribution centers and quantity purchased. Typical ammonia prices at the time of writing are 17¢ per lb in bottles or cylinders, and 4¢ per lb in tank-car lots. About 45 cu ft dissociated-ammonia gas are produced from one pound of ammonia; 1000 cu ft dissociated ammonia requires about 22.2 lb of ammonia and 17 kw hr. Thus, the approximate ammonia cost for 1000 cfh dissociated ammonia is either $3.77 or $0.89 depending on whether the ammonia is purchased in cylinders or tank cars. The power cost is about 17¢ per M cu ft assuming a 1¢ per kw-hr rate. This gives $3.94 or $1.06 per M cu ft dissociated ammonia for materials consumed.

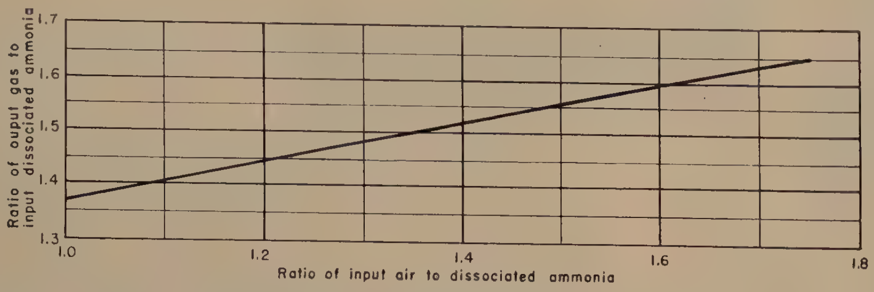


Fig. 18. Effects on output-input ratio when burning dissociated ammonia at various air-gas ratios

BURNING DISSOCIATED AMMONIA

Dissociated ammonia can be burned with air to reduce its cost and inflammability. When it is given this treatment, the hydrogen content can be controlled within a range of 24 percent to 1 percent, leaving nitrogen of 76 percent to 99 percent. The actual analyses for various ratios of air to dissociated ammonia can be determined by reference to FIG. 17.

The gas produced by burning dissociated ammonia with air costs less than dissociated ammonia, because the ratio of the product gas to dissociated ammonia is greater than unity and increases as the air-gas ratio increases. This is brought out in FIG. 18 which shows that the actual volume increase is 37 to 65 percent, the higher values being for the higher air-gas ratios. For example, if 1000 cfh dissociated ammonia is burned to complete combustion with an air-gas ratio of 1.75 to 1, the volume increase is 1.65 to 1, and the output of the atmosphere gas converter in which the dissociated ammonia is burned is 1650 cfh. If the dissociated ammonia should cost $3.94 per M cu ft, the product gas burned at a ratio of 1.75 to 1 would thus cost $3.94 divided by 1.65, or $2.39. In the same manner, a 1-to-1 ratio would give a cost of $2.88. If tank-car ammonia were used, these costs would of course be drastically reduced; and, if the consumption of ammonia should amount to as much as 80,000 lb per year, the cost of storage equipment would be amortized in about two years.

MANUFACTURE AND DISTRIBUTION

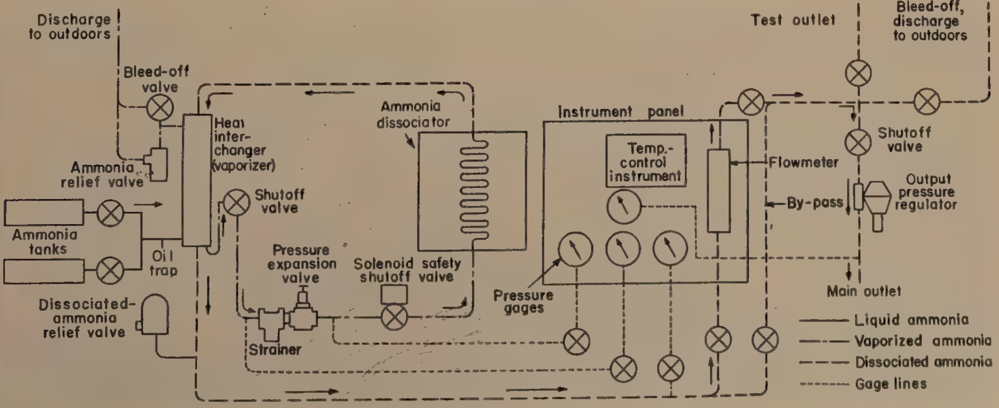
A typical ammonia dissociator is shown in FIG. 19 and its flow diagram in FIG. 20. It is rather common practice to draw liquid ammonia from cylinders or tanks into a combined vaporizer and heat interchanger on the dissociator, as indicated at the left in FIG. 20. Small-sized units, however, rated up to 150 cfh can use ammonia vapors directly from the cylinders and need no vaporizers; in fact, large-sized units supplied by storage tanks of ammonia are also sometimes fed with ammonia vapor. When liquid ammonia vaporizes in cylinders or tanks, a cooling effect takes place which may frost the lines and the tank, if large quantities are consumed, thereby greatly reducing the pressure in the tank unless heat is added. This cooling action does not occur when drawing liquid ammonia.

The insulated vaporizer on the dissociator is provided with electric heating units to supply heat for vaporizing liquid ammonia during the starting up of the dissociator. After the dissociator is in operation, the hot dissociated ammonia circulates through the vaporizer and supplies the necessary heat by interchange, and no extra heat is required.

From the vaporizer, the high-pressure ammonia vapor passes through an expansion valve where the pressure is reduced to 15 psi or less; then the ammonia vapor passes through the dissociating element (FIG. 21) where the ammonia is cracked into its constituents—nitrogen and hydrogen.

Fig. 19. Ammonia dissociator rated 2000 cfh. Control panel (*left*); reaction chamber (*left center*); instrument panel (*right*)

Fig. 20. Flow diagram of ammonia dissociators rated 300 to 2000 cfh



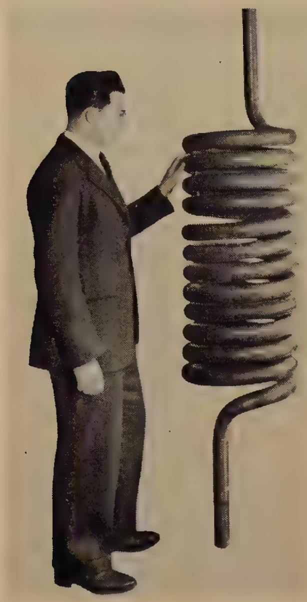


Fig. 21. Typical dissociating element consisting of coiled pipe made of heat-resisting alloy

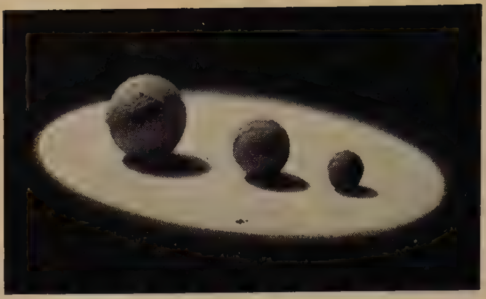
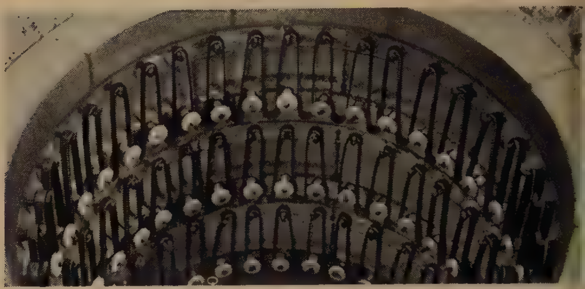


Fig. 22. Refractory balls coated with catalytic material, filling the dissociating element, effectively aid cracking of the ammonia

Fig. 23. Heavy ribbon heating units hung on sidewalls of reaction chamber radiate heat to the dissociating element



The dissociating element is heat-resisting-alloy pipe coiled into a helix, and filled with refractory balls (Fig. 22) coated with catalytic material to assist the reaction. The coil receives heat by radiation from heavy rolled-ribbon heating units (Fig. 23) mounted on the inner side walls of the reaction chamber. The reaction chamber has a refractory lining backed by insulation retained in a sheet-steel casing. The normal operating temperature is 1650 F.

The hot dissociated ammonia next passes through the heat interchanger where it gives up its heat to the incoming ammonia being vaporized. It then goes through a flowmeter and a pressure-reducing valve which controls the discharge pressure.

The instrument panel includes the flowmeter, four pressure gages, a temperature-control instrument, a relay, an alarm bell, and three push-button switches for the control, vaporizer, and alarm-bell circuits.

Control of the flow of dissociated ammonia from the unit is maintained either by the shut-off valve on the high side of the output-pressure regulator shown at the extreme right of the flow diagram (Fig. 20) or by valves elsewhere in the distribution system. The dissociator can be throttled at any rate up to its maximum output with practically no change in characteristics of the output gases. Temperature is held automatically and independently of the dissociated-ammonia output, and the thermal losses are low. As a result, the equipment can be operated practically as economically at reduced output as at full output. In other words, the cost of the dissociated ammonia is almost directly proportional to the output rating of flow.

Table VI shows typical ratings of ammonia dissociators, together with their ammonia and power consumption.

Safety features combined in the unit guard against over-temperature or under-temperature and power failure.

Acknowledgement is made to A. K. Frank of the Schenectady Works Laboratory for his assistance in the preparation of this part of the serial.

(To be continued)

Table VI

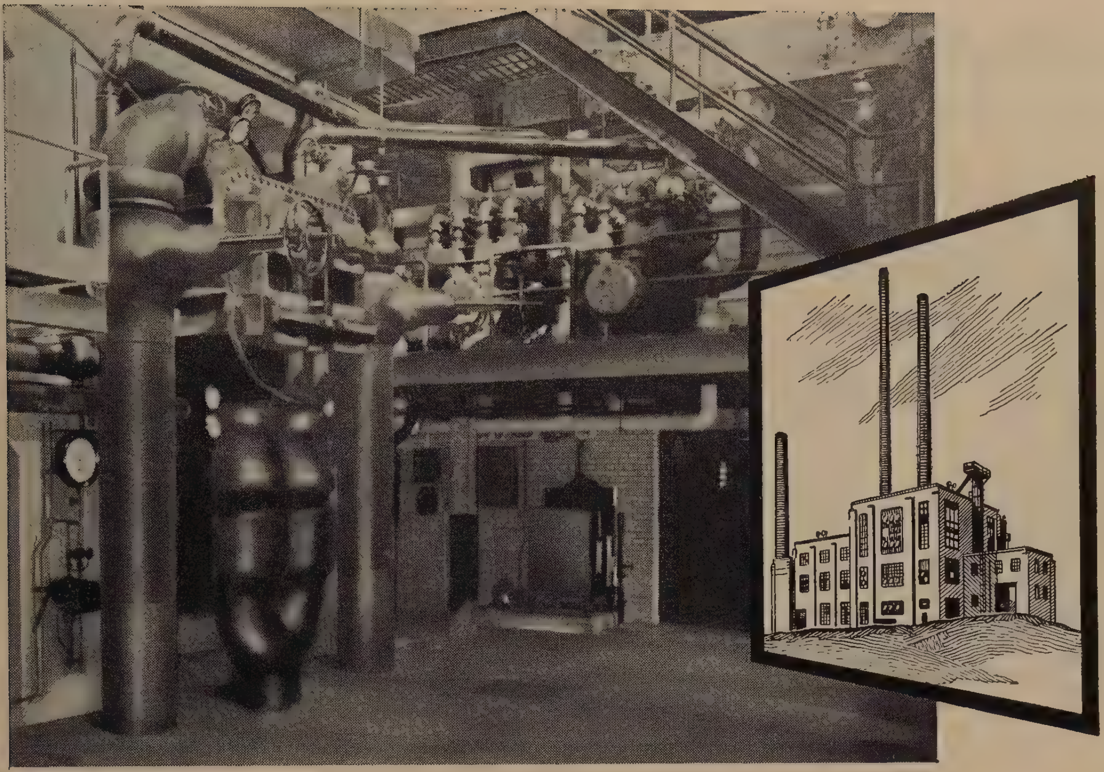
TYPICAL RATINGS OF AMMONIA DISSOCIATORS: THEIR AMMONIA AND POWER CONSUMPTION

Maximum Output Rating (Cfh*)	Approx. Ammonia and Power Consumption at Rated Output at 1650 F		Approx. Standby Losses at 1650 F (Kw-hr per hr)	Dissociator Rating (Kilowatts)	Vaporizer Rating (Kilowatts)
	Ammonia (Lb per hr)	Power (Kw-hr per hr)			
150	3.4	4	2	5	†
300	6.7	7	3	10	1.5
500	11.1	10	3	15	1.5
1000	22.2	17	4	25	2
1500	33.3	25	5	35	3
2000	44.4	33	6	45	4
3000	66.6	40	8	70	‡
4000	88.8	54	10	85	‡

* Ratings based on standard conditions—that is, atmospheric pressure and 70 F. The gas is discharged at any selected pressure from three-inches wate column to 10 lb at a temperature of about 250 F (except from the 150 cfh unit with vaporizer and heat interchanger, in which case it is about 500 F).

† Dissociator does not have a vaporizer.

‡ No heat necessary in the heat interchanger; the unit is designed to be supplied with ammonia vapor (not liquid) from storage tank equipped with suitabl vaporizer.



CITY OF DOVER, OHIO

installs second I-R Condenser

The power plant of the City of Dover, Ohio is an excellent example of the way smaller power plants throughout the country are keeping up with the ever growing demand for power. With the recent addition of a new 4000 kw turbo-generator and Ingersoll-Rand condensing plant, the City of Dover has completed one more step in a long-term expansion program. The new unit was installed under the jurisdiction of W. C. Kammerer and Associates, Consulting Engineers, Cleveland, Ohio and Mr. Waldo Hartline, the City Engineer. The condenser is an Ingersoll-Rand two-pass unit, vertically divided so that one half of the condenser can be operated while the other half is down for inspection or cleaning. In this plant there is also a 2000 kw I-R condenser, installed in 1938, three motor driven circulating water pumps, two boiler feed pumps, four condensate pumps and an air compressor for plant air.

By selecting Ingersoll-Rand condensers, pumps and auxiliaries, the City of Dover has received the benefit of the very latest developments in condenser plant design. If you are planning to expand your present power generating facilities, call in an Ingersoll-Rand specialist. He can show you the latest Ingersoll-Rand developments.

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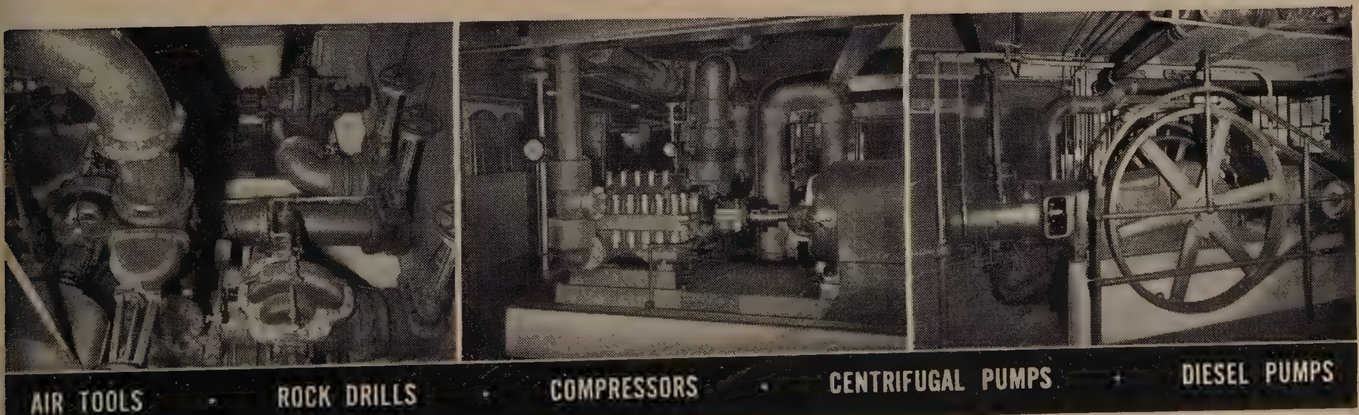

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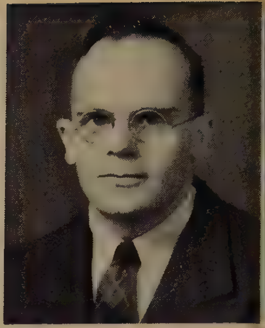
HOW ACCURATELY CAN TIME BE MEASURED?

Unpredictable changes of the order of 4 parts in 100,000,000, detected on rare occasions, perhaps set a limit to the use of the earth's rotation as a standard of frequency, although there appears to be no sound basis for claims that frequencies are known to within one part in a hundred million at all times



By HARRY R. MEAHL

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PROBABLY the earliest record of time standards is of biblical origin and is found in Genesis 1:14—"And God said, Let there be lights in the firmament of heaven to divide the day from the night; and let them be for signs and for seasons and for days and years." Since then many people have had the opinion that there must be a standard of frequency of greater absolute accuracy than that provided by the rotation of the earth upon its axis. Although no substitute has yet been widely accepted, it may be profitable to investigate the absolute accuracy of the presently accepted standard of frequency.

The staff of the United States Naval Observatory uses the mean of a number of observations on the passages of stars to compute corrections for time signals. These time signals are used to check the rates of the quartz-crystal-controlled oscillators maintained by the United States Bureau of Standards, one of which controls the signals emitted by Radio Station WWV and is the U.S. working frequency standard.

Various claims have been made for accuracy greater than that provided by timing the rotation of the earth on its axis. In a paper(1) presented before the Institute of Electrical Engineers in England, C. F. Booth and F. J. M. Laver made the statement that the international measurements of frequency agreed in 1925 to only within 1×10^{-3}, while in 1945 many applications required a frequency stability of 1×10^{-7}, over a period of a day, and absolute standards known to 1×10^{-8} were available.

In a paper(2) presented before the American Institute of Electrical Engineers, B. F. Husten and Harold Lyons stated, "The National primary standard [of frequency] consists of nine quartz-crystal oscillators which are automatically compared with each other and with Naval Observatory time. The absolute value of the frequency of any one of these oscillators is known at all times to within one part in 100 million."

THE PROBLEM: ABSOLUTE ACCURACY

In their paper Booth and Laver stated that the precise time intervals required for the calibration of frequency standards are determined astronomically and are generally made available by means of radio time signals. Unpredictable changes of the order of 4 parts in 100,000,000 have been detected on rare occasions, they said, and these set a limit to the use of the earth as a standard.

In the United States, too, the theory has sometimes been advanced that other standards of frequency are more nearly accurate than the rotation of the earth. During the last quarter of 1946 the U.S. Naval Observatory noted an apparent acceleration in the rates of all of its clocks amounting to about four thousandths of a second per year. Extremely careful investigations were made to determine the cause. The calculations were reworked, eliminating from consideration all except the clocks running most uniformly. This did not substantially change the results.

National Bureau of Standards Radio Station WWV, near Washington (D.C.), broadcasts six important technical services (five of them worldwide) 24 hours a day: standard radio frequencies, the standard musical pitch, time announcements, standard time intervals, standard audio frequencies, and radio-propagation-disturbance warnings

As there was some reason for suspecting that the zenith tube was not in the best operating condition, observations made with the six-inch meridian transit circle were reduced for the determination of time and the results compared. These results were found to be in close agreement at the beginning and end of the period, but not in the middle.

Irregularities of the clocks, errors of observation, or a combination of the two would probably have been accepted as the explanation of the situation, had not

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

(1) "A Standard of Frequency and Its Application," by C. F. Booth and F. J. M. Laver, *Journal of I.E.E.*, vol. 93, part III, no. 24, July 1946.

(2) "Microwave Frequency Measurements and Standards," by Benjamin F. Husten and Harold Lyons, *Electrical Engineering (AIEE Technical Paper 48-49*, Dec. 1947).

apparently similar changes in clock rates been reported elsewhere. This led the Naval Observatory to say that changes in the rate of rotation of the earth had been suggested as a cause, and that the matter was one requiring thorough investigation and careful study.

In this connection Captain Guy W. Clark, Superintendent of the U.S. Naval Observatory, stated, "The present standard of time is the rotation of the earth. Unfortunately this standard is not a perfect one. Judged by the longitude of Mercury, for example, the rate of the earth's rotation in 1929 was about one part in twenty million faster than it had been in 1909. Since 1929 the earth has appeared to slow down again, but only slightly. It is generally considered that the changes in the rate of rotation are slow, and that over short periods, such as a year, the effect is small. The truth of this assumption cannot be positively proven at present."

All this raises the questions: How can the absolute accuracy of quartz-crystal-controlled oscillators be known to one part in a hundred million at all times when the standard of time used to calibrate them apparently changes by greater amounts in an unpredictable manner? Within what limits are the determinations of time accurate?

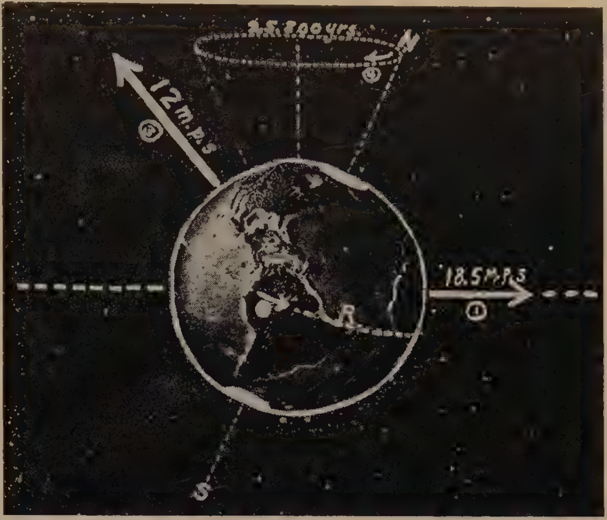
SOURCES OF ERROR

Astronomers observe erratic changes in their determinations of time, of the order of one part in thirty million, which they believe are caused by changes in the refraction of the atmosphere. It is standard practice to reverse a zenith tube in its mounting and to make observations on several stars to reduce to the minimum the effect of any mechanical imperfections in the instrument on the computed time interval. Booth and Laver estimated the following errors in time-signal transmission and reception:

Vagaries in clock contacts	0.1 millisecond (approximately 1 part in 500,000,000 for one day)
Electronic chronometer	0.01 millisecond
Receiver delay	0.4 millisecond
Transmitter and radio path delay	0.5 millisecond

Observed variations from day to day about the mean drift curve are approximately two parts in one hundred million.

An attempt to estimate the errors in rate determinations by astronomical observations has been made at the U.S. Naval Observatory by comparing the time determinations made by the Observatory with those made by other national observatories. Several years of international time-signal comparisons were examined with this point in mind. Five-day means were used to derive clock rates between pairs of such points ten days apart. Ten-day rates of the Washington timepieces were thus determined, based on foreign time determinations and international time-signal comparisons. The rates agreed within one part in a hundred million with those derived from Observatory determinations. Thus it seemed reasonable to suppose that the errors in Observatory rates average less than one part in one hundred million, although occasionally they may rise to one part in fifty million. These figures, however, do not include the effect of variation in the earth's rate of rotation.



Some motions of our planet: (1) revolution eastward around the sun; (2) rotation eastward; (3) with sun and system among the stars; (4) conical spin of the axis

BASIS FOR CLAIMS

There appears to be no sound basis for the claims that frequencies are known within one part in one hundred million at all times. Such claims have been made because of the belief that, although a calibration within one part in ten million is the best possible in a period of one day, a higher calibration accuracy is achieved by averaging the comparisons over periods up to 150 days and by drawing a smooth curve through these values. This obviously gives a measure of mean frequency and does not indicate short-time stability.

These mean values, however, have been used as though they were instantaneous because of the stable performance of groups of quartz-crystal-controlled oscillators for weeks, or even months. In considering this, it must be remembered that each oscillator has a rate and that there are a large number of things which can affect it. In fact, each circuit element must be considered a source of possible random frequency variation when parts in one hundred million are being counted. History shows that the rates of all oscillators change from time to time; some even change sign, and occasionally an oscillator stops oscillating. Although the rate of an oscillator may become as small as a few parts in a billion per day, if there were nothing by which to calibrate it, the oscillator would in time get far from correct frequency. Even where several oscillators have shown changes in rate in the same direction, it is significant that they have not been of exactly the same magnitude nor have they been truly simultaneous.

ATOMIC CLOCK

The National Bureau of Standards has recently announced an "atomic clock" which is said to have a

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NOTICE
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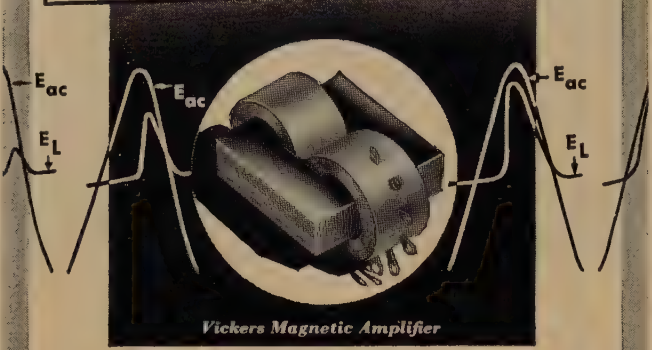

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MEASUREMENT OF TIME

(Continued from preceding page)

stability of approximately one part in ten million in its early stage of development.

It is expected that better stability and other advantages over the quartz-crystal-controlled clocks now used to control Station WWV will be obtained as the development of the atomic clock is continued.

CONCLUSIONS

From the facts considered here three conclusions can be drawn:

(1). In the present state of the art it is reasonable to claim that the frequency of a quartz-crystal-controlled oscillator may be known at all times within one part in ten million, as calibrated by astronomical observations of the rotation of the earth.

(2). A considerable amount of extremely exacting work of the type going on at the National Bureau of Standards and at the U.S. Naval Observatory, and in similar institutions abroad, will be needed to obtain and maintain accurate knowledge of the stability of the earth's rotation and, hence, of the accuracy with which a frequency standard may be known.

(3). An absolute accuracy of one part in ten million is extremely difficult to establish even though means are available for comparing frequencies with a precision of one part in a billion.

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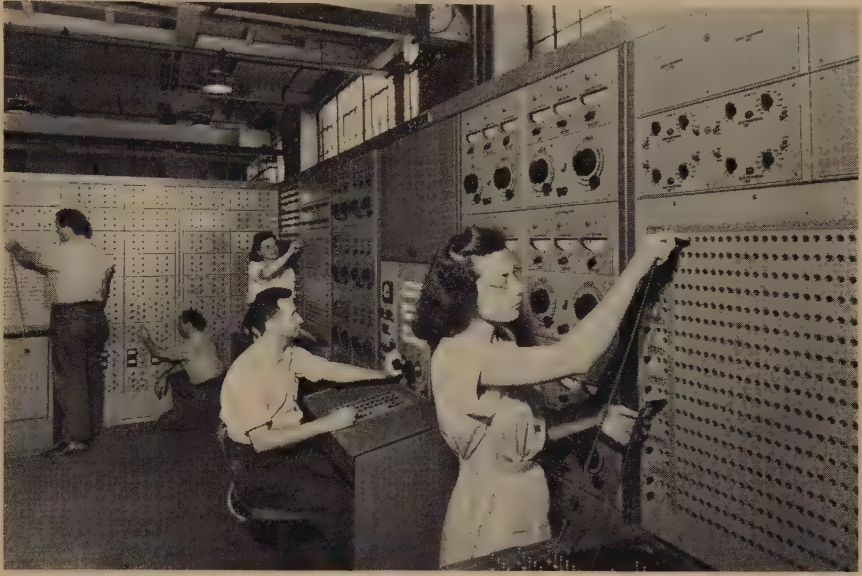
High-pitched sound from a little whistle, ocused to a point by an ordinary headght reflector, can perform such stunts as naking cotton burn and floating bits of ork in mid-air. The simple apparatus, onstructed of materials easily available o any craftsman, has been built for exmining the peculiar properties of ultraonics.

Sound from the one-inch-long whistle, vhich is blown by compressed air, is ocused to a point as light is brought to a oint by a concave mirror. When bits of ork are placed directly above the focal oint they remain suspended, ladderashion, one-half wavelength apart. When otton is held at the focal point, its articles are agitated by the unheard ound until the cotton smolders.

The whistle is a hollow tube with air lowing across its mouth. The pitch can e adjusted by moving a tiny piston which its inside the tube. Engineers usually set he whistle to make sound waves with a requency of about 25,000 pulsations per econd; the human ear cannot hear requencies much above 17,000 pulsations er second.

Electrical Wizard

This network analyzer, which reproduces in miniature the electric circuits of vast power networks, was shipped recently to the Bureau of Reclamation, at Denver, where it will be used in the design of projected power systems or to determine the effect of an alteration on an existing system. In the solution of many mathematical and scientific problems capable of expression in electrical equivalents—the study of vibrations in shafts and machinery, the flow of fluids or gases through a network of pipes, or the flow of air over the wing of a plane—its answers are obtained in a fraction of the time required by longhand computation



How and Why Metals Break

Recent investigations by scientists have hown that the fracture of metals begins vith extremely small cracks, nuclei which row into a large split when enough ension is applied. Prior to this investigaion, it was usually assumed that the break n the metal occurred instantaneously hroughout the sample.

The metals study was begun with reearch into how a column of fluid breaks. t soon became apparent that bubbles vhich break a water column have much n common with cracks in metal.

When a pull is applied to a column of fluid or a bar of metal, the column or bar will hold together if the tension is not great enough to do the work of making the nuclei (bubbles or cracks) grow into a break. For every tension there is a critical bubble or crack size. If, when a certain tension is applied, there are nuclei of the critical size or larger, they will grow rapidly, causing the sample to break. However, nothing will happen if only nuclei smaller than critical size are present, according to the scientists. The smaller the nucleus, the bigger the force needed to expand it into a break.

Similarity has been noted between the behavior of metals and that of moisture in trees and plants. The giant California redwoods are a good example of how much tension a fluid can stand without breaking, according to the scientists. The larger redwoods pull columns of water in their trunks as high as 300 ft above the ground, under a tension of about 130 psi. Water under so low a pressure would be expected to boil, but if this were to occur in a tree, the column of sap would be broken and the tree would die. The redwoods survive because there are no nuclei of the critical size for the 130-lb tension exerted on the sap. Before the boiling process in fluids or the breaking process in metals can take place, there must be nuclei.

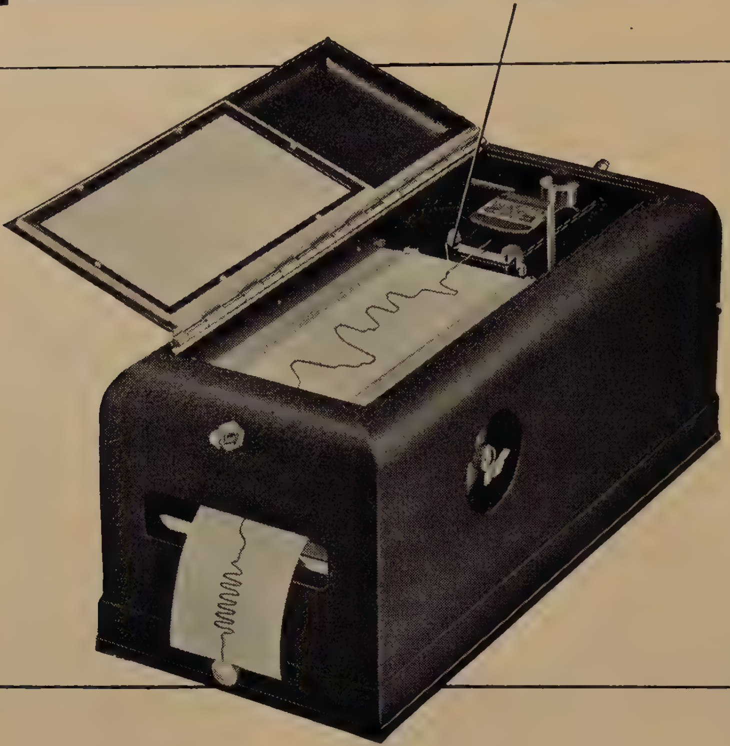
A model of an iron grain, or crystal, with cork spheres indicating position of the atoms. Chance activity of atoms along the boundaries of such grains, moving from one grain to another, causes tiny nuclei to be constantly forming and disappearing. If enough tension is applied, nuclei will grow—along the boundaries, not through the grains.

New Electrical Measurements Laboratory

An ultramodern five-story brick and steel building, which will house a new completely equipped electrical-measurements laboratory, is now in process of being erected at West Lynn (Mass.) by General Electric's Meter and Instrument Divisions. The structure is designed to provide the best possible facilities for research and development in the field of electrical measurements and permit greater co-

(Continued on next page)

This Oscillograph draws an INSTANT picture of electrical impulses!



Today when saving time costs is so important, your best bet for an *immediate* picture of electrical impulses is with Brush Oscillographs. No more delays with photographic development. *Instantaneous,* permanent, ink-on-paper recordings by Brush Oscillographs make their use almost unlimited. Accurate recordings of strains, pressures and countless electrical phenomena can be made over a frequency range of D.C. to 100 c.p.s. Today Brush Oscillographs are available in Single, Double and Six Channel models. The magnetic Pen Motor is available separately for incorporation into equipment such as medical, geophysical and other highly specialized designs. Whenever desired, recordings may be stopped for notations on chart-paper.

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HIGH LIGHTS (Continued)

ordination between laboratory and engineering personnel.

Scheduled to be completed late in 1949 the building will be H-shaped, with a long central section and two wings for good light and ventilation. A 500-capacity auditorium will be located in one wing

The Laboratory will occupy the largest amount of the building's 142,000 sq. ft of floor space, and it will be provided with the most modern equipment for the development of new products, materials and processes. Engineering and drafting personnel will be grouped adjacent to the Laboratory area. The structure will also include offices, exhibit rooms, and customer-meeting rooms for administrative and sales personnel.

Battery Vitalizer

A new electric device called a "battery vitalizer" keeps the starting power of automobile batteries at summertime operating levels during cold winter months Connected to ordinary 110-volt household current and plugged into a cigar-lighter receptacle on an automobile's dashboard the device supplies a slight current to the battery through the ignition system maintaining chemical activity in the battery.

The battery vitalizer keeps automobile batteries at summertime operating conditions during cold weather

Best efficiency is obtained when the battery is operating at a temperature of about 80 F, but efficiency drops to 40 per cent or less when temperature falls to zero or below. The vitalizer is harmless to the battery even though it is kept operating indefinitely; moreover the device might serve to lengthen battery life, since keeping the battery fully energized during cold weather assures maximum power and life

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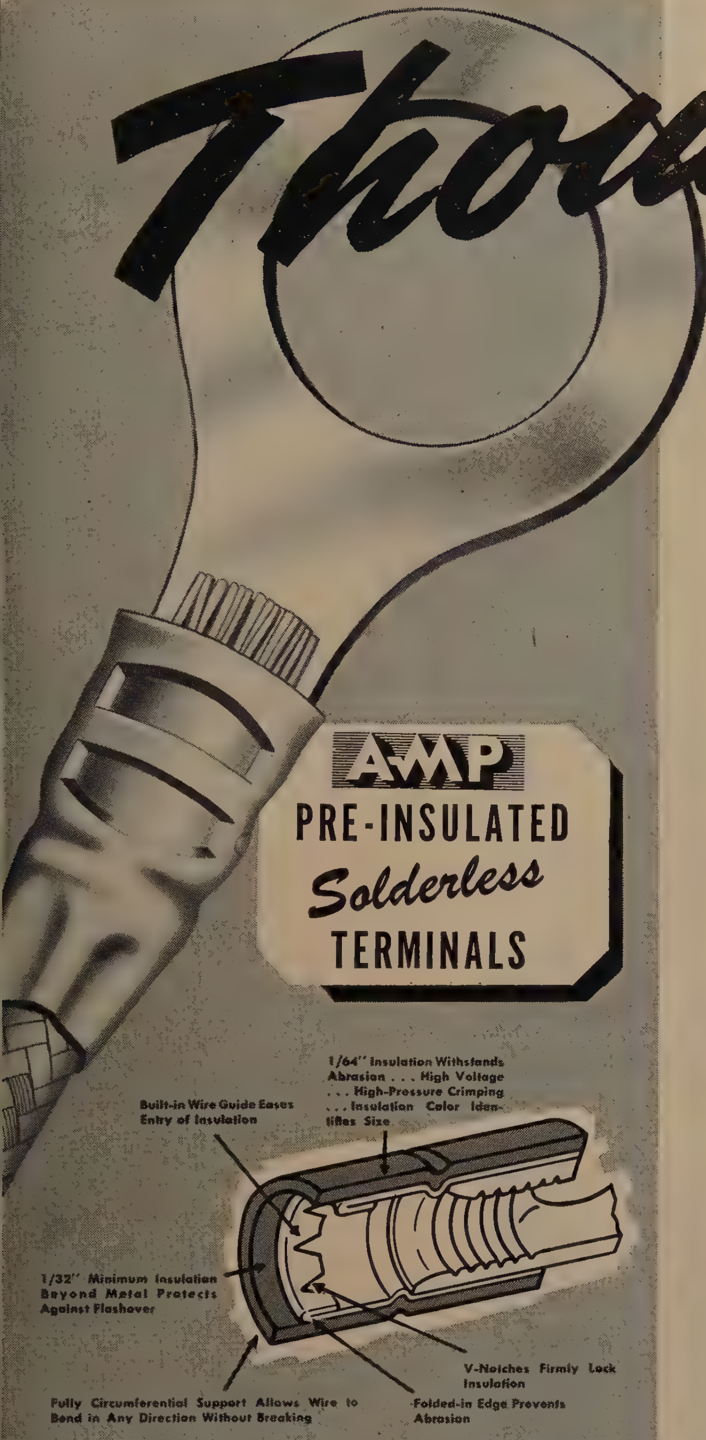
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Available for wire sizes 22 to 10 inclusive in a wide variety of tongue shapes and stud hole sizes, AMP patented Pre-Insulated Terminals are eliminating costly and unnecessary installation methods. Samples will be sent upon request together with Catalog Section 10.

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High-speed Nut Setter

An improved, more powerful, portable, electric Speed-O-Matic impact nut setter tightens or removes nuts, bolts, studs, and lag screws. Also, it can be used effectively for drilling, tapping, etc. It is torqueless; will not twist in operator's hands when nut becomes tightened. It drives nut or bolt 1750 rpm at free speed. At point of resistance, the unit automatically delivers 3000 impact blows per minute and tightens to a torque of over 200 ft-lb on a ¾-in. bolt. It is instantly reversible for removing bolts or nuts. Silman steel forgings and ball and roller bearings are used for maximum endurance.—*Speed-O-Matic Sales, Inc., 4639 W. Washington Blvd., Chicago 44, Ill.*

Meter Multiplier

Features not available before in a V.U. meter multiplier of comparable size are offered in a new attenuator. Measuring only 1¾ in. in diameter, the unit provides five-step Straight T performance in a control size normally limited to ladder and potentiometer circuits. A pair of extra terminals increases the utility of this unit. The V.U. meter is connected to the auxiliary pair of terminals on the multiplier when in the OFF position, thus enabling the meter to be used for volume indication on another line, tube checking, and other purposes.—*Shallcross Manufacturing Co., Collingdale, Pa.*

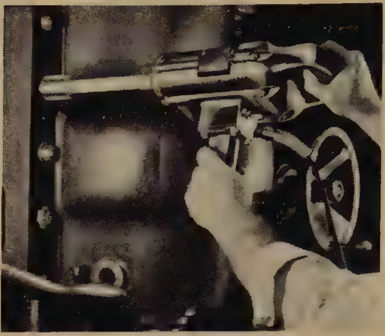
Blade Checker

The Pant-O-Scriber automatic machine for inspection of turbine blades, checks contour, twist, thickness, width, etc. in less than one minute. A permanent inspection record of each blade is obtained at the time of inspection. After the blade is traced, a co-ordinated rotating scriber automatically produces an exact scribing on a specially coated glass plate of each section as traced.

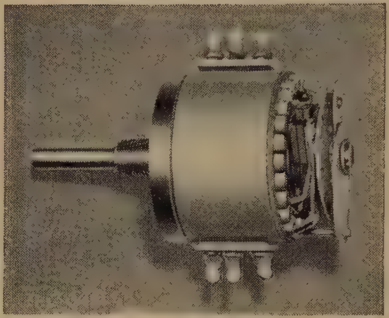
A precision master inspection chart, actual size of the blade, is used together with the scribed plate for inspection purposes. These are projected on a screen to any desired size, using a vertical lantern slide projector. Permissible tolerances are shown on a bridge tolerance chart. A special measuring stage, which fits over the lantern slide projector, is supplied for engineering and research purposes. This stage is used for measuring the amount of deviation of twist, displacement, thickness, contour profile, etc.—*Engineers Specialties Division, The Universal Engraving & Colorplate Co., Inc., 980 Ellicott St., Buffalo 8, N. Y.*

Slide Switches

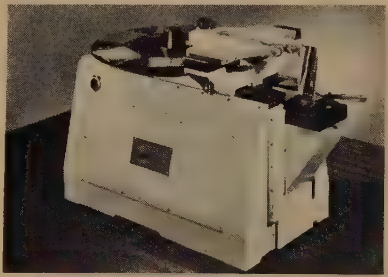
Two new slide switches to meet the need for small, inexpensive, sturdy units having sufficient current-carrying capacity for electric tools, fans, appliances, toys, and other equipment. Type SS26 is a single-pole single-throw switch, and Type SS26-1 is a single-pole double-throw switch. Both are rated 1 amp at 125 volts d-c, or 3 amp at 125 volts a-c, and are Underwriters approved. Colored knobs, terminal enclosures, and other special features can be supplied. The new switches are sturdily constructed for long, trouble-free performance and are low in price.—*Stackpole Carbon Company, St. Marys, Pa.*



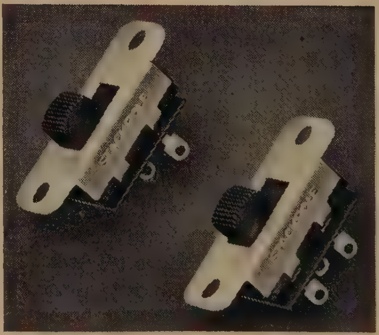
High-speed Nut Setter



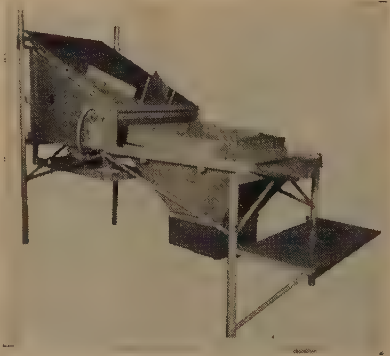
Meter Multiplier



Blade Checker



Slide Switches



Mechanical Separator

Arc-welding Electrodes

Four new electrodes (Types W-60, W-61, W-62, and W-95) for use in a wide range of arc-welding operations. The Type W-60 is designed to meet the need for an electrode with a low-hydrogen coating and manganese-moly analysis. The Type W-61, a low-hydrogen electrode of a moly-vanadium composition, can be used with either a-c or reverse-polarity d-c to weld a wide variety of low-alloy steels. Type W-62 can be used for producing weld deposits having high impact properties at sub-zero temperatures. Designed to deposit hard wear-resisting weld metal in all positions, using a-c or d-c, the Type W-95 is suitable for surfacing dipper teeth, tractor cleats, mud and sand pumps, sizing screens, etc.—*General Electric Co., Welding Equipment Divisions, Schenectady 5, N. Y.*

Solder

A new indium-lead solder alloy No. 50 designed to meet the demand for a solder with a melting point midway between those of the tin-lead solders and brazing alloys. The new solder contains no tin, melts at 600 F, exhibits short plastic range, and has good wettability factor. Tests indicate a holding strength of 3500 psi and a tensile strength of 5200 psi, with a high degree of ductility. Available in all standard wire gages, as well as ribbon form; the solder can also be ordered to specifications in preformed shapes such as rings, washers, pellets, disks, etc.—*Soldering Specialties, Summit, New Jersey.*

High-speed Punch

A new high-speed Electropunch, Model BS 1, utilizes a high-temperature silicone insulated coil within a sturdily constructed solenoid. This permits continuous operation at better than 150 cycles or blows per minute which deliver an impact of more than a ton. The punch is suitable for staking; riveting and marking; wire cutting; blanking; and forming and drawing of metals, plastics, fabrics, leather, etc., but it is particularly designed for high-speed operation. Weighs only 45 lb and requires less than 1 sq ft of bench space.—*Black & Webster, Inc., Needham, Mass.*

Mechanical Separator

A new Roto-Finish motor-driven mechanical separator for removing parts from chips or for separating mixed chips into various sizes. The unit consists of a welded steel frame with an inclined surface on which is located a hoist pan serving as a hopper, and a waist-high separating table which supports a mechanized shaker-screen assembly. The inclined surface for the hoist-pan support is adjustable for correct gravity flow of parts and chips onto the screen.

The screen assembly can be elevated from a horizontal to an inclined position by a height of four inches on the end nearest the hoist pan. This height, plus the motion provided by the motor drive, separates parts from chips, automatically discharging the parts at the opposite end. Parts do not leave the screen before the separation is complete because the discharge end is tapered and provided with a lift gate.—*The Sturgis Products Co., Sturgis, Michigan.*

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- Two separate, completely independent, lectron guns.
- Individual circuits for intensity, focus, nd X-, Y- and Z-axis modulations.
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WHAT IT DOES...

Only the dual-beam oscillograph can simultaneously...

- Compare the complete signal and an ex- anded portion thereof.
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- Compare electrocardiograms picked up rom two different points.
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ype 5SP- Cathode-ray Tube.
Sweep-frequency range: 2 to 30,000 saw- ooth cps.
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X-axis amplifier response: flat to dc., down db at 150 kc.
Deflection: for all amplifiers 1 v. dc./in. pprox.
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DUAL-BEAM

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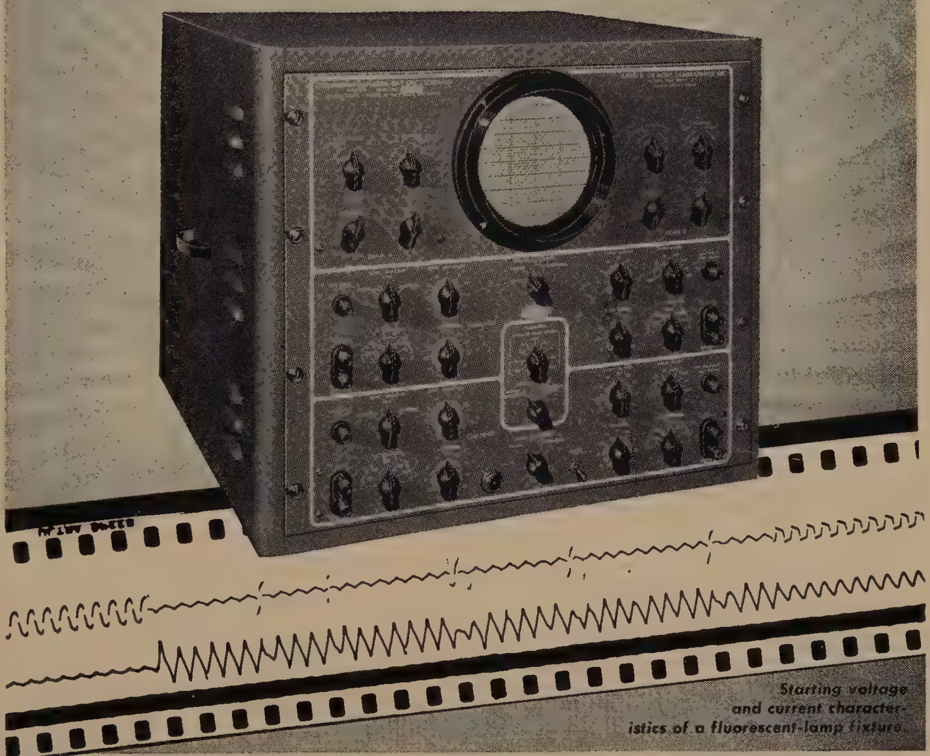

Starting voltage and current characteristics of a fluorescent-lamp fixture.

The introduction of the Type 279 Dual-beam Cathode-ray Oscillograph makes available for the first time a really dual instrument with *separate and wholly independent* electron guns. The circuits associated with each gun are also distinct and separate. For the first time, separate time bases are provided for each beam with provision for applying one time base to both guns, if so desired. For the first time, an oscillograph is offered which alone can perform the applications listed.

Now it is possible to superimpose two complete traces without a cumbersome and costly optical system or by the use of time-sharing devices. And with the P2 screen, the light output is more than sufficient for visual observation or for photographic recording of high-speed transients.

Other advanced features are the built-in calibrator and the ability to respond to direct-current signals.

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LATHES—New 13-in. and 14½-in. swing precision lathes equipped with one-inch maximum collet capacity headstock spindles are described and priced. Listed also are chucks, collets, and other accessories for use with these larger spindles. Catalog No. 73. Four pages.—*South Bend Lathe Works, 205 E. Madison St., South Bend 22, Indiana.*

MATERIAL TESTER—Describes Model L universal tester, a precision instrument of seven different ranges, for use in industrial plants, universities, and laboratories for testing materials of tensile strength from a few pounds to 160,000 psi. Photographs show the simple construction for tensile, compression, transverse, and shear testing; the handling of flats and rounds; fixtures for fabrics, cord, rope, wire, wood, and adhesives; and the easily read dynamometers interchangeable for all capacities. Four pages.—*W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44, Ill.*

PNEUMATIC CONVEYING SYSTEMS—Typical examples of Convair systems designed to convey materials both hot and cold, wet and dry, by using air, gas, or steam are set forth. These systems are employed by glass, food, chemical, coal, and other industries. Bulletin No. 102. Eight pages.—*Convair Corporation, 1501 Potomac Ave., Pittsburgh 16, Pa.*

RESISTORS—Comprehensive data are given on characteristics and specifications of the advanced-type BT insulated fixed-composition resistors. Includes performance standards for ⅓-, ½-, 1-, and 2-watt types in addition to numerous charts and curves. Bulletin B-1. Twelve pages.—*International Resistance Co., 401 No. Broad St., Philadelphia 8, Pa.*

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SAFETY POSTERS—The 1949 Directory o Occupational Safety Posters contains 74 illustrations of two-, three-, and four-colo posters, ranging in size from 8½ by 11½ in to 10 by 12 ft, and classified under 15 sec tions. Posters are conveniently indexe under specific accident hazards. Price 50¢ Seventy-two pages.—*National Safety Council, 20 No. Wacker Drive, Chicago 6, Ill.*

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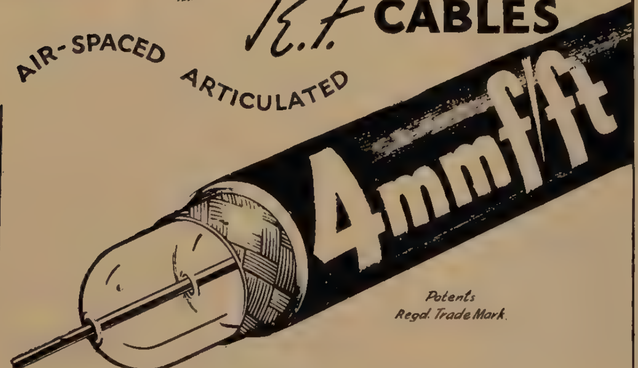

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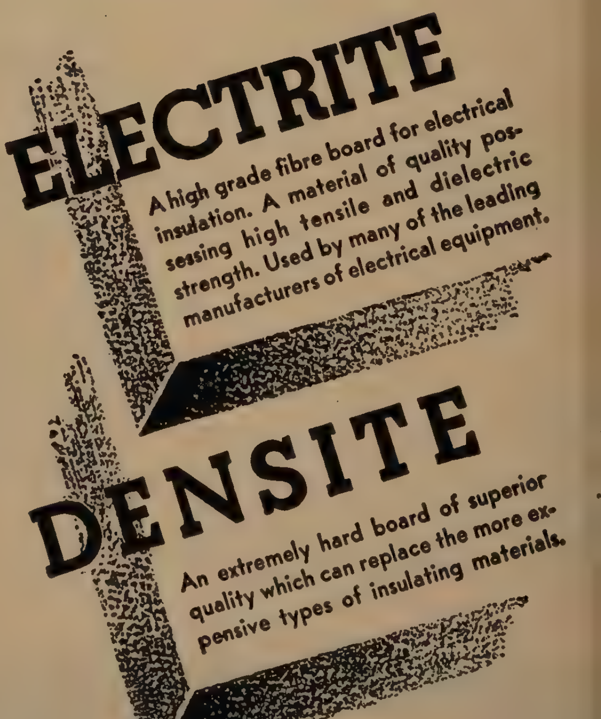

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

ANSFORMERS—THEORY AND CONSTRUC- N

C. Sealey—International Textbook Co.,
anton, Pa. 1948. 256 pp. $3.00.

ın elementary textbook—the work of
Engineer-in-Charge of Transformer
sign for the Allis-Chalmers Manufactur-
Company—covering concisely and
ırly various phases of the transformer
: theory, calculation, construction, and
ration. It is liberally illustrated with
grams and photographs.

ılthough the preface does not state how
book came about or for whom it was
ended, it is particularly well adapted to
needs of servicemen, maintenance men,
orentices, and correspondence students.
chnical graduates also may find items
interest in it, as the book is up-to-date.
e strength of the paper and the binding
o indicate anticipation of harder usage
ın that expected in an office.

A. BOYAJIAN

HAT ELECTRONICS DOES

ı Zeluff and John Markus—McGraw-
ll Book Co., Inc., New York. 1948. 316
. $3.00.

Here is a short, easily understood, non-
hnical description of more than four
ndred interesting applications of electron
oes in industry. The reader is given a brief
mpse of the manner in which electronic
vices operate in many fields of human
ivity to provide us with better products
lower cost, more comforts and conven-
ces in life, better medical aids and safe-
ards to prolong our lives, and increased
otection and striking power in time of war.

This is interesting and instructive reading
"nontechnical" persons desirous of ex-
ıding their knowledge of electronics. It
o can serve as reference material for
ose engaged in industry who may be
skilled in electronics yet realize some of
potentialities as an industrial tool.

H. W. LORD

RMING OF AUSTENITIC CHROMIUM-NICKEL AINLESS STEELS

sembled and edited by Vsevolod N.
ivobok and George Sachs—The Inter-
tional Nickel Co., Inc., New York. 1947.
1 pp. $4.00.

In 1926 the first commercial heat of
stenitic chromium-nickel stainless steel
s made. Since that time the use of stain-
s has grown tremendously, and much
ll and know-how has been developed in
e forming of these materials. However,
ıch of this information was obtained from
lividual efforts at various plants and was
en regarded as a trade secret. Messrs.
ivobok and Sachs have assembled and
ited the up-to-date methods and proc-
es used in forming stainless steel, pre-
ıting the information in a simple, straight-
ward manner which is easily understood.
e use of a great many illustrations show-
actual parts and the operations per-
med on those parts is especially helpful.

The book begins with a description of the
chanical properties and forming charac-
istics of stainless steels. Heat treatments
ed after forming are next considered.
om this beginning, the factors involved
the design, layout, and preparation of blanks for forming are considered and equipment, tools, and lubricants described. The various types of forming and the methods used are then described and illustrated.

An excellent index allows the reader to find easily and quickly information on any phase of the forming operations.

This comprehensive, well-written book provides a wealth of information heretofore unavailable to most persons, and should be of great value to both technical and nontechnical men who use or make stainless steel parts.

M. C. ROWLAND

QUALITY CONTROL IN INDUSTRY

John G. Rutherford—Pitman Publishing Corp., New York. 1948. 219 pp. $3.50.

Statistical methods for use in quality control have come to furnish a particular fascination for technical men. Much good for control activities has resulted from this situation, and an ever-increasing number of reports are being published about successful results from statistical methods.

Such unprecedented interest in statistics has not been an unmixed blessing. The book shelves and magazine racks have been filled with material on industrial statistics, at the expense of adequate coverage of other important phases of quality control.

It is refreshing, therefore, when a book appears which addresses itself—at least in part—to some of these other issues. The first one third of *Quality Control in Industry* treats of such important topics as quality-control organization, economics of product quality, reports and records, and personnel training. Discussion is couched in general terms and is based upon actual industrial applications.

The remaining portion of the book covers statistical methods. While the presentation of statistical theory contains little new material, the examples that it employs are practical and useful.

Mr. Rutherford's book is more nearly a survey of selected quality-control topics than a detailed analysis of any of these topics. This is both its strength and its weakness. The book will be of interest to men and women new to this activity. It will not, however, be overly useful to quality-control practitioners, for whom its statistical materials may not be new nor its discussion of organization sufficiently fundamental.

A. V. FEIGENBAUM

TELEVISION AND F-M RECEIVER SERVICING

Milton S. Kiver—D. Van Nostrand Co., Inc., New York. 1948. 216 pp. $2.95.

This book has been written as an aid to those who service television and FM receivers. Radio theory is presented only insofar as it may be required to solve particular service problems.

As is the case in any "practical" treatment of a complex subject, it is very difficult for an author to determine just how much explanation of theory to present in order to make his book authoritative yet brief enough to be useful. The author appears to have achieved a judicious balance between theory, installation, and service work in the present book.

(Concluded on next right-hand page)

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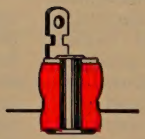

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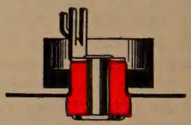

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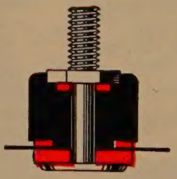

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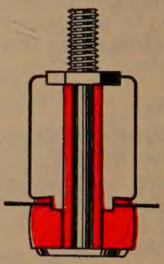

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OOK REVIEWS (Continued)

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Necessary descriptions of fundamentals of eration have been aided considerably by ear, well-drawn illustrations and schematic agrams so placed in the text as to assure a aximum convenience in reading.

The chapters covering television sweep d synchronizing circuits have been parularly well done, giving one of the best positions on the standard RMA synchrozing signal that has appeared.

To the serious service man who is desirous improving his abilities in the fields of levision and FM this volume will be pecially useful. But it should also be of terest to other technical people who, alough they are not immediately concerned th radio subjects, are interested in relaely simple expositions on the operation of levision and FM receivers.

C. G. Fick

MERICAN ELECTRICIANS' HANDBOOK (Sixth Edition)
errell Croft (Revised by C. C. Carr)—cGraw-Hill Book Co., Inc., New York. 48. 1789 pp. $6.00.

This handbook is intended to provide inrmation on the basic characteristics of eration, bases for selection, methods of stallation, and maintenance procedures for electrical equipment. Primarily written for the practical men—linemen, wiremen, contractors, and operators—the material is presented in very simple terms without recourse to higher mathematics. The engineer will find the book useful as a reference on present-day practices in construction, operation, and application of a wide variety of electric equipment.

This edition follows the main material headings contained in the previous editions: fundamentals, properties and splicing of conductors, circuits and circuit calculations, general electrical equipment, transformers, generators and motors, outside distribution, interior wiring, electric lighting, and wiring tables. The material, however, has been rewritten in most cases to include recent developments (amplidynes, synchros, fluorescent-lamp developments, farm wiring, etc.) and make all information correspond to the 1947 edition of the National Electrical Code.

A new division has been added, entitled Electron Tubes and Circuits, which gives a brief description of vacuum-tube fundamentals and a survey of the major types of circuits used in industrial control. This attempts to fill a definite need for such information on the part of maintenance men in the electrical industry; however, it is felt that a more detailed explanation of vacuum-tube fundamentals will be required by the average practical man than is included in this book.

In general, the description of equipment and procedures is sufficient for a reference book. There are, however, some minor defects; for instance, in the section on transformers, tables are given on average characteristics of distribution transformers, but no units are given for the listed values of no-load losses and total losses and no definition is given in the book for the listed values of percent impedance. Other than a few small items such as these, the book represents a definite improvement in caliber over previous editions.

K. O. Straney

BATTLEFRONTS OF INDUSTRY
David O. Woodbury—John Wiley & Sons, Inc., New York. 1948. 350 pp. $3.50.

This is the story of Westinghouse in World War II. Beginning with a glimpse of peacetime operations, the story proceeds to defense planning, war orders, and thence to the laboratories, engineering offices, and shops where the orders were filled. The reader feels again the urgency of the war program and the increasing tempo of development and production as he is carried along from guns to turbines, radios, binoculars, radar, bug bombs, electric torpedoes, jet propulsion, and finally to uranium and the atom bomb. It is a moving, human story of men and machines, of hard work and inspired judgment, of many successes and few failures.

To the average reader, the book opens an unusual panorama of industrial technology. In those who helped fight the war on the industrial front, it will stir reminiscences of parallel situations in their own experience. These "insiders" may feel the author overemphasizes the apparent impossibility of meeting each new demand for more production, the confusion caused by inadequate specifications, and the difficulty in meeting specified standards. Perhaps so, but perhaps it merely seems so because our troubles always seem smaller in retrospect.

C. Schabtach

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

AIR CONDITIONING

Freon Versus Air-cycle Cooling of Automobiles, by Harold Woodhouse. *Refrig. Engng.*, Oct. 1948; v. 56, pp. 313-315, 336.

Adoption of the air-cycle expansion turbine for aircraft cooling indicates this same system may be suitable for passenger cars.

Individual Control, Flexibility in Office-building Air Conditioning, by Ralph E. Phillips and Louis H. Wagenbrenner. *Heat. Piping & Air Cond.*, Sept. 1948; v. 20, pp. 71-75.

Features of the air conditioning for the new General Petroleum Corp. office building.

AERODYNAMICS

Transonic Separation, by Vernon Outman and Arthur A. Lambert. *Jour. Aero. Sci.*, Nov. 1948; v. 15, pp. 671-674.

The problems of avoiding airflow separation, air-frame shaking, and control-surface buffeting at transonic flight speeds.

CERAMICS

Fundamental Research for the Navy in Ceramics, by R. D. Jackel. *Am. Soc. Nav. Engrs. Jour.*, Nov. 1948; v. 60, pp. 552-564.

Recent findings as to production, properties, and applications.

ELECTRIC LIGHTING

Mercury Lamps Redesigned for Improved Light Output and Performance, by Edward B. Noel. *Illum. Engng.*, Nov. 1948; v. 43, pp. 1044-1060.

Covers the design of mercury lamps in relation to the loading of the arc-tube wall and the use of larger outer jackets. The influence of the type of jacket glass upon the formation of detrimental hydrogen is discussed.

Power-plant Lighting Needs Careful Design, by S. L. Chapin and H. E. Wehr. *Elec. Lt. & Pr.*, Sept. 1948; v. 26, pp. 110-116.

Analysis of the lighting of representative plants provides valuable data on current lighting practices and suggests improvements to effect increased operating efficiency.

Rapid-action Starter Switch for Fluorescent Lamps, by Th. Hehenkamp. *Philips Tech. Rev.*, Nov. 1948; v. 10, pp. 141-149.

A new type of starting switch, which reduces the interval between closing of the circuit and ignition of the lamp.

FOUNDRY PRACTICE

Gating Systems for Metal Casting, by William H. Johnson and William O. Baker. *Foundry*, Oct. 1948; v. 76, pp. 68-73, 252.

The effects of gate design on the flow and turbulence of liquid steel as a casting is poured.

Precision Casting — A Production Achievement! by Chester S. Ricker. *Tool Engr.*, Sept. 1948; v. 21, pp. 27-29.

Use of the Antioch process for making aluminum-alloy castings. Not to be confused with the "lost wax" investment process.

ISOTOPES

Atoms Go to Work for Industry. *Aut Ind.*, Oct. 1, 1948; v. 99, pp. 24-28, 82, 85-86

The first of two articles on industria applications of isotopes.

Can the Atom Serve You? by A. N Wecksler. *Mill & Factory*, Sept. 1948; v 43, pp. 95-99.

Tells about some of the things bein done with isotopes by industry.

Isotopes for Industry, by Colin Carmichael. *Steel*, Oct. 4, 1948; v. 123, pp 74-75, 108, 111-112.

Unlike the generation of atomic power use of radio-isotopes is not around som future corner. It is here now, and industr is daily finding new fields of application

MACHINE-SHOP PRACTICE

Navy Devises Ingenious Planer an Boring-mill Setups, by Rupert LeGrand *Am. Mach.*, Oct. 7, 1948; v. 92, pp. 96-100

How gun-factory personnel worked ou manufacturing procedures that save tim when jobs are run in any productio quantity.

POWER PLANTS

1948 Modern Plant Survey. *Power*, Oct 1948; v. 92, pp. 583-635, 636-637, etc.

Technical highlights of utility and industrial power-plant construction to meet unprecedented load growth; tabulated engineering features of over 700 new steam and hydroelectric stations. Includes statistics of station equipment, by name of plant.

Power From Process Steam, by William E. Zelley. *Elec. Engng.*, Oct. 1948; v. 67, pp. 956-959.

The desirability of investigating power generation in industrial plants which have need for large quantities of process steam. Careful individual analysis of a plant is required in order that the possibilities may be explored.

SOUND RECORDING AND REPRODUCTION

Variable-area Recording with the Light Valve, by John G. Frayne. *Soc. Motion Pict. Engrs. Jour.*, Nov. 1948; v. 51, pp. 501-520.

Various types of variable-area track, including standard and push-pull, may be obtained by various arrangements of the light-valve ribbons.

X-RAYS

Broad- and Narrow-beam Attenuation of 500-1400-kv X-rays in Lead and Concrete, by H. O. Wyckoff and others. *Nucleonics*, Nov. 1948; v. 3, pp. 62-70.

Report on x-ray shielding investigations, together with attenuation curves for use in designing x-ray protection.

Formation of Optical Images by X Rays, by Paul Kirkpatrick and A. V. Baez. *Optical Soc. of Am. Jour.*, Sept. 1948; v. 38, pp. 766-774.

Several conceivable methods for the formation of optical images by x rays are considered, and a method employing concave mirrors appears most promising